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OPERATION ON A DEFUNCTIONED DISTAL COLON

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IN THE surgery of the distal colon, the principle of carrying out operations and allowing the wound in the bowel to heal in a distal colon which has been completely defunctioned has revolutionized my operative results in the surgery of this region. Not only has this method improved my results, but also it has enabled me to perform with success operations on the distal colon, such as the various forms of sutured anastomosis and anastomoses of the sigmoid to the rectum, operations which I never dared attempt in the functioning distal colon. The principle of operating on the defunctioned colon has, therefore, not only enabled me to save many lives, but also it has permitted me to save the continence of many patients, who, otherwise, with the ordinary system of operating, would have been left with artificial anuses.

By a defunctioned distal colon I mean one which has been completely disconnected from the alimentary canal, so that it cannot be soiled in any way by even the smallest quantity of feces; one from which the fecal contents have been washed out; and one which has been allowed to remain functionless until such time as the bacterial content has been considerably reduced—reduced on the principle that if, experimentally, a segment of bowel be completely isolated and thus deprived of its function, in the process of time, it will lose most of its bacterial content. The process of debacterialization—if I may coin such a word—brought about by the defunctioning of the distal colon and the lapse of time, can be hastened by daily lavage of the excluded segment, with saline solution, with solutions of low surface tension, or with weak antiseptic solution.

The two important points in this method of operating on the defunctioned distal colon are first that the operation is carried out under favorable conditions—absence of septic feces, functionless collapsed and retracted colonic walls, and low bacterial content; and second, that the

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wound in the intestine is allowed to heal under these conditions. And of these two points, the healing of the wound in a bowel devoid of content and without function is much the more important.

Arising out of this method of operating is, what I consider, another advance in the surgery of the colon, and this is that the disconnection, to defunction the distal colon, which is made at the hepatic flexure or in the proximal part of the transverse colon, can be made more or less continently; that is, the patient need not be soiled with the fecal contents, nor need he wear a colostomy cup. The semifluid contents of the cecum and ascending colon can, as a rule, be "corked" into this segment of bowel, as if they were corked in a bottle—the patient can wear a corked tube fitted into the small fistulous opening which serves as a disconnecting anus. The contents of the cecum can then be emptied or evacuated by a "wash-out" every twenty-four hours. As a rule, there is very little soiling of the abdomen, rarely any irritation of the skin, and never any smell. I have never been able to obtain the same degree of continence and the same degree of comfort with an opening in the sigmoid region, that is, with the ordinary artificial anus.

In the past, like most surgeons, I was very worried over the result of my surgery in the region of the distal colon. No matter how carefully and aseptically and skillfully I made an anastomosis in the distal colon, the mortality rate of these operations was high—as high as 30 per cent. I soon learned the value of draining the bowel by cecostomy or some other means as a preparation for a resection and an anastomosis; but although the results were better, the operation on the still dirty, perhaps functioning, bowel, and the healing under the same conditions, especially in a metabolically diseased, anemic, and toxic cancer patient, were still attended with a considerable mortality rate—a mortality rate too high to be tolerated in these days of successful surgical operations.

In an effort further to improve my results, I resorted to all sorts of modifications of Paul's technique. In cases of carcinoma of the sigmoid or of the transverse colon, so favorably situated that this operation could be carried out, my results were most successful; indeed, no better results could be desired. But the difficulty with this method was that it was so successful that I was tempted to employ it for growths in the upper or lower part of the sigmoid—positions which were not favorable to its performance—and I found that I was not removing enough of the mesentery. And as a consequence of this, the remote results—results which, in the more or less favorable carcinoma of the colon, should be good—were not all that could be desired. I found, too, that this method was of very little use in the inflammatory conditions of the sigmoid; that is, in conditions such as large inflammatory diverticular tumor of the sigmoid, in which the whole sigmoid was involved, and in which the mesentery and the bowel were rigid and contracted. In such circumstances, that is, in an innocent condition, in which I needed most

of all to employ an operation, the danger of which was not great, I could not employ operations based on the principle of Paul.

In looking round for better methods for operating on the colon, and particularly on the distal colon, I was struck by the fact that it was its "cess-pool"-like function which was the great "stumbling-block" in its surgery. I felt that if I could deprive the distal colon of its function, remove its contents, let it lie dormant for some time until it had lost a good deal of its germ content, just as the isolated experimental loop lost its organisms, I could carry out any operation on it and get just as good repair in it as I would in any other part of the intestinal canal. And that is exactly what has happened: I have been able to carry out sutured end-to-end or side-to-side anastomoses in old and debilitated cancerous patients; to remove almost the whole of the sigmoid in inflammatory diverticular tumor and eventually join the upper part of the sigmoid to the upper part of the rectum; to remove carcinomas of the lower end of the sigmoid, and anastomose the middle of the sigmoid to the divided rectum; to remove inflammatory diverticular tumors of the sigmoid, which, by the ordinary methods of operating, would be quite irremovable; to remove a series of innocent adenomas of the sigmoid by slitting it longitudinally, dissecting them out of the mucous membrane, and then closing the lumen of the bowel; and to cure the rectovesical fistula arising from diverticulitis of the sigmoid.

A faithful adherence to this simple principle of operating on the distal colon has enabled me to excurse, with success, into fields of colonic surgery, into which I had never dreamed of wandering. It has, of course, reduced the mortality rate of my colon surgery to one which bears comparison with the mortality rate of my other operations in the abdominal cavity. I must admit, however, that this success has tempted me to explore realms of what I might call "derelict" colon surgery; that is, it has tempted me to operate on many hopeless-looking cases of carcinoma of the sigmoid, because I learned that after defunctioning the distal colon for some time, some growths that appeared to be inoperable lost their adhesions to surrounding structures, became smaller and operable. As one would expect, the excursion into this surgical field led to as many failures as successes. But the successes were absolute ones, for, otherwise, if the ordinary standards of colon surgery were followed, these cases would have been certain deaths; and the failures would have died under any circumstances.

THE APPLICATION OF THE PRINCIPLE OF OPERATION ON THE DEFUNCTIONED DISTAL COLON

In the surgery of the distal colon, there are two main fields: the surgery of malignant conditions, the main one of which is carcinoma of the sigmoid; and the surgery of innocent affections, which comprise inflammatory diverticular tumors with their complications, rectovesical

fistulas, etc., single or multiple adenoma of the sigmoid, and endometrioma of the lower part of the sigmoid or the rectosigmoid junction.

Of these two fields of surgery, the one concerned with inflammatory conditions of the distal colon gives the most dramatic results, because on account of their innocency time is not a factor. And furthermore, on account of a reasonable amount of continence in the disconnecting anus, and, therefore, because discomfort and invalidism are not considerations, patients are not in the least disturbed by the defunctioning of the distal colon for a year or two. Thus, the distal colon can be defunctioned until such time as the bowel is almost germ-free and all inflammation has disappeared, and even until most of its effects on the tissues have been repaired.

In the field of malignancy, time is a great factor, and the distal colon cannot be defunctioned (and prepared) for a period any longer than three weeks or a month. But, in this field, there has been this advance: it is the septic character of the contents of the normal colon which constitutes the main danger in its surgery. In the carcinomatous distal colon, this septic character is increased many fold because it is chronically obstructed; for scarcely any carcinoma of the colon comes to the surgeon before it exhibits symptoms—colicky pains and distention—which are those of chronic intestinal obstruction. Thus, in the carcinomatous distal colon, the pathogenicity of the bacterial contents of the colon is greatly increased, the colonic walls are thin and their thin walls are almost permeable by germs, its lymphatics are full of infective organisms and its tissue vitality toxically spoiled—all conditions in which an operation would almost certainly lead to peritonitis, and in which repair could scarcely be expected. In such circumstances, complete defunctioning of the distal colon, especially when it is prepared by daily lavage—even if it be for the short period of a month—brings about such a profound change in the pathogenicity of the bowel contents, and in its walls, that the mortality rate of operations in the carcinomatous colon is greatly reduced. Not only does the short period of defunctioning improve the local resistance of the patient's colonic tissues, but also the patient's general resistance. It certainly permits the growth to be removed with safety. But repair, after an anastomosis between the segments, although ever so much safer than in other methods, is nevertheless not so safe as the repair of anastomosis when it is allowed to take place in a distal colon which has been defunctioned for many months.

Even in the malignant field, however, it is possible to take full advantage of this principle of operation on a defunctioned colon, for the reconstitution of the continuity of the bowel—the dangerous part of colonic operations—can be made in a colon which has been defunctioned for any desired period; and thus, the immediate results of the surgery of malignant conditions can be made almost as safe as those of innocent conditions.

It is in what I have termed the "derelict" phases of carcinoma of the sigmoid colon that this method is of great advantage. A distal colon can be defunctioned for a month. The growth can then be resected, and the divided end of the functionless sigmoid implanted in the upper and lower end of the wound—an operation of little severity and danger. The patient may then be sent home for twelve months. During this time, he will be able to live a fairly normal life, because his disconnecting anus will be more or less continent and he will, therefore, be able to carry out his usual work. Thus, adequate time—a most important factor—is allowed for improvement of his general and local conditions. His general condition should greatly improve, because, his growth being removed, he will be free not only from the systemic toxic infection of the growth itself, but also from that caused by his chronic intestinal obstruction. Any systemic metastasis, which might not have been obvious at the operation, will become manifest. Locally, the bacterial content of his colon will have greatly decreased, and the vascularity of the bowel wall, particularly that in the divided ends, will have become definitely established. Thus, a sutured anastomosis of the colon segments —the dangerous part of an operation for the removal of a malignant growth in the colon—can be carried out under such ideal general and local conditions that there should be no more danger to the patient than that of any other abdominal operation.

The Method of Operation on the Defunctioned Distal Colon.—This method of operation on the defunctioned colon involves the following:

1. A complete disconnection of the proximal from the distal part of the colon, so that the distal colon can be completely defunctioned.
2. A preliminary exploration of the abdomen.
3. The construction of a disconnecting anus, which
   a. completely disconnects,
   b. is more or less continent,
   c. can be easily closed,
   d. is situated well away from the area of the operation.
4. The preparation of the defunctioned distal colon.
5. The type of operation carried out on the defunctioned distal colon.

The Complete Disconnection of the Proximal From the Distal Colon. —It is important that the distal colon be completely disconnected from the rest of the alimentary canal. The ordinary spur colostomy does not bring about a permanent complete disconnection; for its spur soon begins to draw in when some fecal contents follow the plane of the mucous membrane and soil the distal segment. Complete disconnection is obtained by cutting the bowel across and inserting the ends into separate openings in the abdominal wall. The disconnection is made in the proximal limb of the transverse colon; or if the transverse colon be short, at the hepatic flexure.

Preliminary Exploration of the Abdomen.—Advantage is taken of the slight first-stage operation of making a disconnecting anus, for the purpose of defunctioning the distal colon, to make a preliminary exploration of the abdomen. An incision a little over two inches in length is made in the upper part of the left rectus muscle (Fig. 1). This incision is preferably made very small, because through it the disconnecting anus is going to be made and therefore it may become infected; and in the presence of infection, a small wound is more manageable and less dangerous to the patient than a large one. Exploration of the whole abdomen through this small opening can be most effectively carried out by vaselining the gloved hand (Fig. 2). The lubricated gloved hand slips

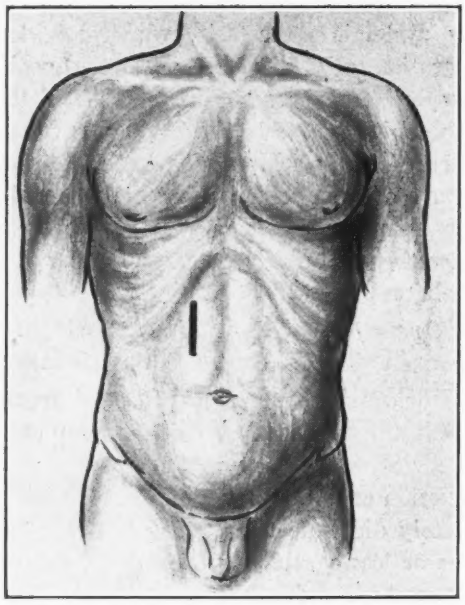

Fig. 1.—Showing the position of the small incision made over the upper part of the right rectus muscle. Note the smallness of the incision (about 2½ inches).

readily through the small incision; the omentum or intestines do not cling to it, and thus, an exact and reliable exploration of the growth, the liver, and of the whole abdomen can be made. With this simple aid, it is surprising to experience, for the first time, the comfort and ease with which an exploration, usually difficult under such circumstances, can be carried out.

The main object of the exploration is to make an examination of the growth and of any glandular involvement with a view to its operability, and to ascertain if there is any metastatic spread of the growth, which would prohibit its radical removal.

The Construction of the Disconnecting Anus.—In regard to this disconnecting anus, there are four requirements: (1) that it should completely disconnect, (2) that it should be more or less continent, (3) that

it should be capable of being easily closed, and (4) that it should be situated well away from the area of the operation. The first is obtained by dividing the bowel and implanting the divided ends into separate openings in the abdominal wall; the second, by making a small fistula-like anus at the beginning of the transverse colon with an opening so small that it can be easily occluded; the third, by combining the small fistulous anus with a very long spur; and the fourth, by making the disconnection in the upper right part of the abdomen at either the proximal part of the transverse colon or the hepatic flexure.

The Steps in the Technique.—

1. The incision: Already described and used for exploratory purposes; two and one-half inches long in the upper part of the right rectus.

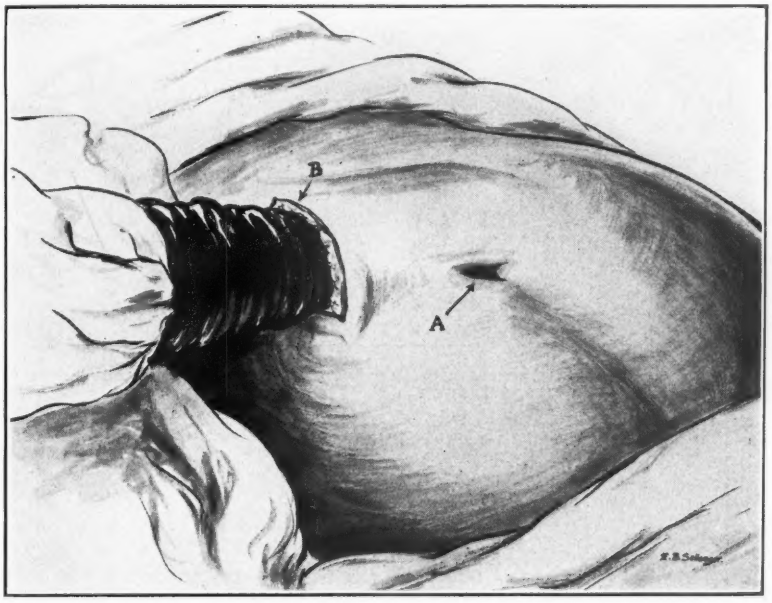

Fig. 2.—Drawing, made from photograph, of an exploration of the abdominal cavity, being made through this small incision, with a vaselined gloved hand. The drawing shows the operation viewed from the end of the table. *A* is the umbilicus; *B*, gloved hand inserted into the small exploratory incision through which the disconnecting anus will be made.

2. Formation of the long spur: If the transverse colon be long, its proximal part is drawn out of the abdominal wound and a tube passed through the apex of the loop as shown in Fig. 3. The loop is now stretched to its full extent, and its limbs are connected together by a running suture, so as to make as long a spur as possible (Fig. 4). The spur should be four or five inches long. If the transverse colon be short, the long spur is made by suturing the proximal part of the transverse colon to the ascending colon, the apex of the loop then being the hepatic flexure.

3. The parietal peritoneum is sutured round the neck of the loop (Fig. 5).

4. Button-hole openings (through only part of the abdominal wall) are made one inch on each side of the incision. Through these openings, Kocher clamps are applied to the bowel (as in Fig. 5), which is then

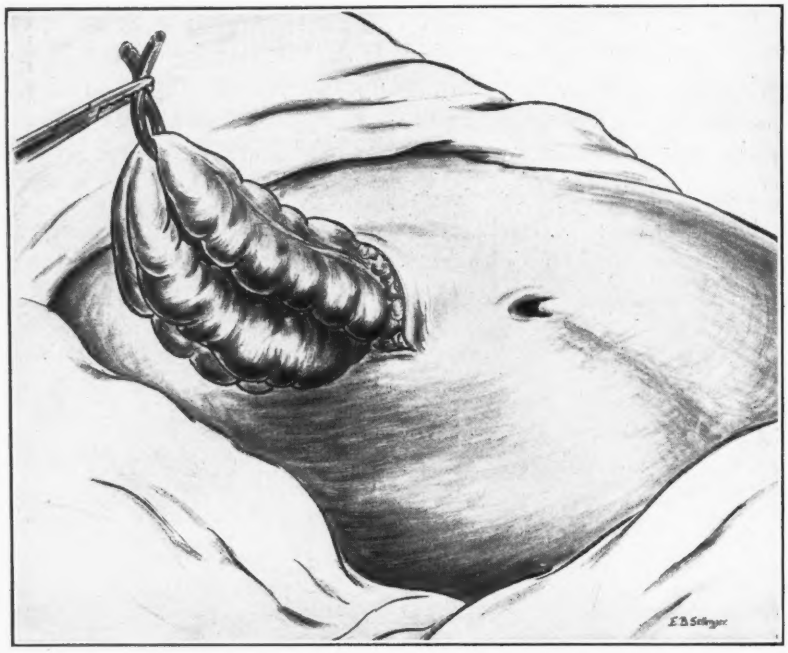

Fig. 3.—Proximal part of transverse colon drawn out of the abdominal wound and a tube passed through the apex of the loop.

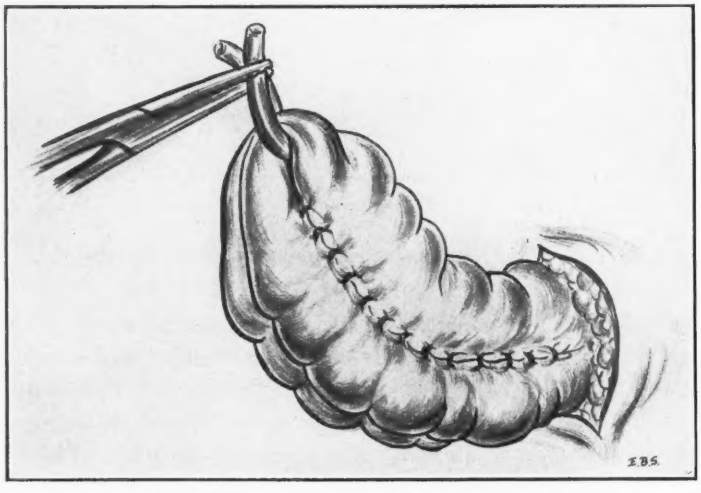

Fig. 4.—Running suture connects the limbs of the loop.

divided, between them, with a diathermy knife, and its cut ends, after being coagulated with the diathermy current, are drawn by the forceps into the button-hole openings (Fig. 6). The skin edges around the

bowel ends are now sutured, so as to make a pair of tiny fistulas, for it only requires a very small opening to allow egress of the semifluid

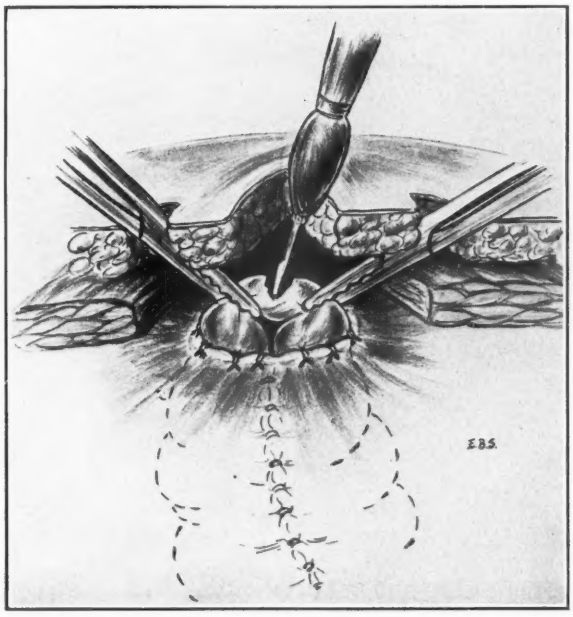

Fig. 5.—Kocher clamps applied to the bowel through two small openings in the abdominal wall, which do not include the muscle of the abdominal wall.

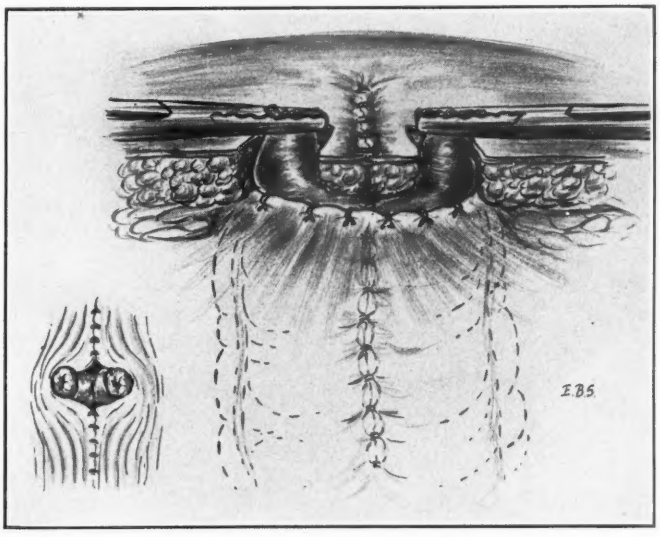

Fig. 6.—Diagrammatic section to show the two cut ends of the bowel drawn up through the small openings by the Kocher clamps, and the main wound sutured. Inset shows position of muscle in relation to the ends of the bowel.

contents of the ascending colon, and there is very little danger of the fistula closing, because, from its nature, it must always function.

In order that there should not be the slightest intestinal obstruction with such a small anus, the proximal Kocher clamp is taken off after

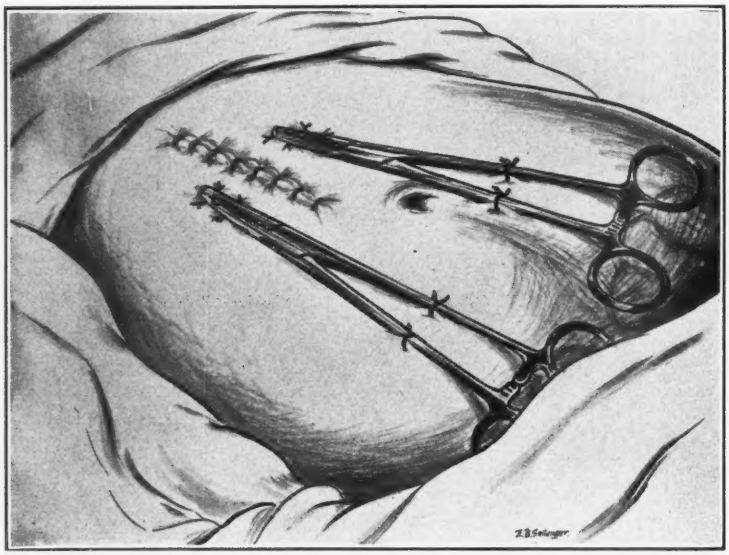

Fig. 7.—Kocher clamps in position on the abdomen.

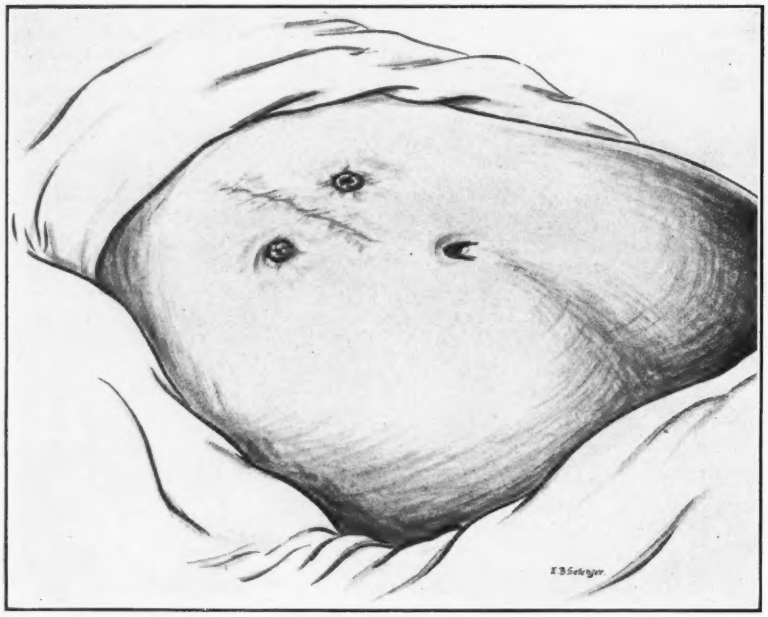

Fig. 8.—Shows the disconnecting anus.

twelve hours, but in order to keep the bowel ends in proper position, the distal one is left on for several days. Fig. 7 shows the two clamps in position on the abdomen.

Thus, this technique produces an anus giving all requirements: complete disconnection; the small opening which is easily occluded but through which the semifluid contents of the cecum and ascending colon can discharge; the very long spur, the crushing of which permits early restitution of function; the anus situated well away from the region of the future operation. Fig. 8 is a drawing showing how small is the finished disconnecting anus. Very rarely in a case of acute intestinal obstruction, the bowel is so intensely distended that it is impossible to

Fig. 9.—Photograph which shows how small these colostomy openings can be, and yet function properly.

make a spur. In these circumstances, a cecostomy should be made and when the bowel regains its normal size, a disconnecting anus can be made.

Management of the Disconnecting Anus.—Fig. 9 is a photograph which shows how small these colostomy openings can be, and yet function properly. One surgeon, on whom I carried out this form of colostomy, was able to control the bowel contents for twenty-four hours with a toy balloon. He then took it out, leaned over a dish, emptied his bowel, cleaned the anus, and put back the balloon, and he would then be free from fecal discharge for another twenty-four hours.

The best way, however, to control this artificial anus is to insert into it an occluded rubber tube which has a caliber large enough to fit firmly into the opening and to which a large flange of sponge rubber is fixed. Fig. 10 is an illustration showing the use of this tube. A sponge-rubber flat pad, fitted round this flanged rubber tube, was used by one patient, who kept herself clean by this device. The tube is fitted with a cork. The patient can once or twice in the twenty-four hours, either attach a funnel and tube wash-out apparatus to this tube, and wash out her cecum and ascending colon and then recork it; or she can remove the corked tube, lean over a basin, completely empty the contents of her cecum and ascending colon, clean herself, and reinsert the corked tube. She will then, if the anus be correctly made, remain clean for twenty-four hours, that is, until she next attends to her anus. Over a period of

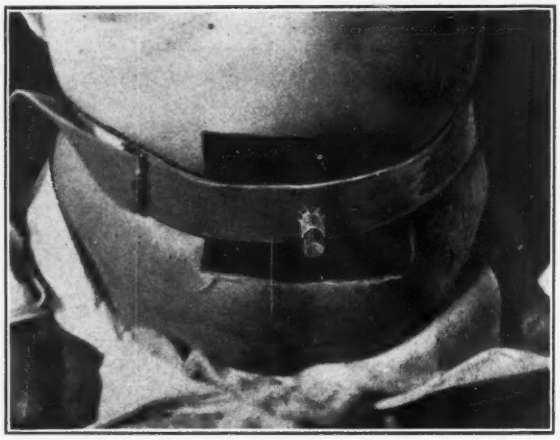

Fig. 10.—A photograph of the proximal colic anus which has been controlled by the use of an occluded tube.

eighteen months, this anus has never leaked. Some anuses are better than others, or perhaps some patients manage theirs better than others.

This small artificial anus in the proximal part of the transverse colon where the contents are fluid, somewhat like the cecum, is comparable to the opening which I am accustomed to make in the cecum through the base of the appendix—an appendicostomy—for chronic colitis. Patients have been able to keep themselves clean over a period of many years by using an occluded No. 14 catheter in these openings.

Preparation of the Excluded Distal Colon.—The contents of the distal colon are now washed out, if possible, from the abdominal fistula. It may also be found necessary to wash out the rectum from below the growth. (Fig. 11.)

Lavage with antiseptic solution helps to diminish the bacterial content. In addition to lavage, I have also used instillations of cod liver oil, the vitamin content of which is highly bactericidal. The length of the preparation period is varied according to circumstances. In the case of car-

cinoma with obstruction, three weeks are required to relieve the toxic effects of the obstruction. Sometimes I have found considerable difficulty in getting the colon clean, especially after a barium meal. The barium has accumulated in a hard cricket-ball-like mass in the ampulla of the rectum. In some cases, I have found it necessary to insert a stomach tube into the opening in the distal colon and purse-string it into the artificial anus, in order to get sufficient pressure of fluid in the excluded segment of the colon to wash out fecal lumps.

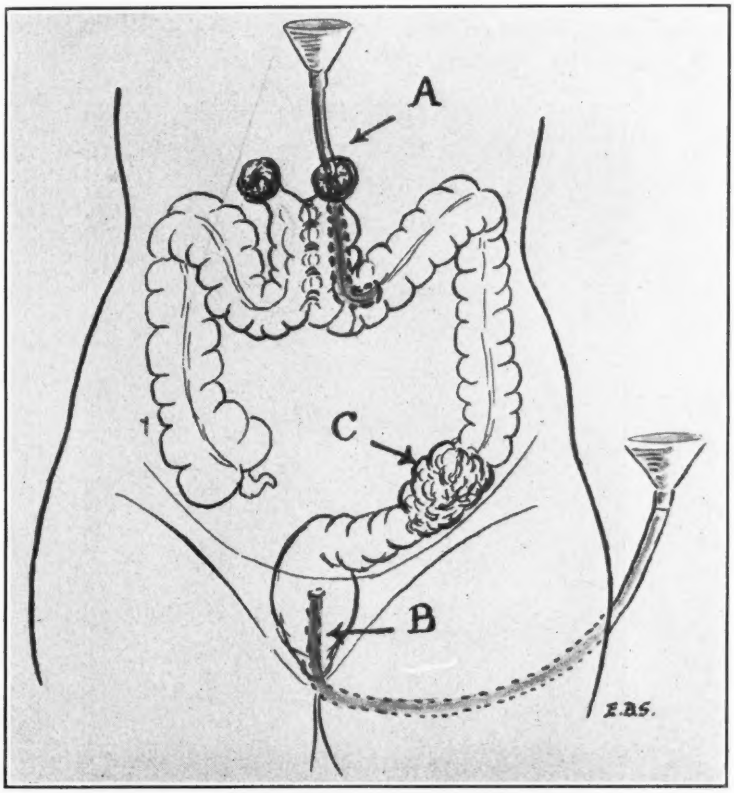

Fig. 11.—Diagram to show how the bowel is prepared by being washed out from the colostomy opening in the distal colon. *A* indicates a tube connected with a funnel inserted in the colon—when the obstruction is complete the rectum also is washed out from below; *B* indicates the tube in the rectum; *C*, the position of the obstruction.

Closure of the Disconnecting Anus.—The closure of these small disconnecting anuses is very simple. A very long enterotome with a narrow, almost cutting, generously bevelled edge is used. Its length makes a very deep opening in the long spur; its generously bevelled edges produce a graduated pressure, and thus makes a wide area of contact and therefore a safe anastomosis between the two limbs; its narrow crushing—almost cutting—edge cuts quickly through the spur. Thus, with this form of enterotome, a connection can be made between the proximal and the distal segment in a few days. (Fig. 12.) See also Fig. 13 which shows

an illustration of the enterotome. The blades are vaselined before use, introduced separately, and then connected up with the screw *A*. *B* is a cross-section of the blades. Fig. 14 is a diagram showing the enterotome applied.

Through the deep anastomosis formed by this long enterotome, all the fecal contents pass, rather than up through the fistula-like anus. The consequence is that, except for a small fistulous opening, which may discharge a little feces or perhaps only air, function is restored in a few days.

The small fistulas can be closed with a local anesthesia, but very often they close naturally.

Fig. 12.—The enterotome in position.

The Type of Operation to Be Carried Out on the Defunctioned Distal Colon.—

1. Partial sigmoidectomy with sutured anastomosis.
2. A rectosigmoid resection with sutured anastomosis.
3. Rectosigmoid resection with telescopic anastomosis.
4. Extensive sigmoidotomy for the removal of single or multiple adenoma.

Sutured Anastomosis in a Functioning Distal Colon.—Whatever may be the opinion in regard to the soundness of making a sutured anastomosis in reconstituting the bowel after an ileocolic resection of the proximal

colon, it is now conceded by those surgeons who have had experience in the surgery of the colon that it is unsound and dangerous to use this form of anastomosis in connecting up the distal colon after resections.

The difficulties and dangers of a sutured anastomosis in the functioning distal colon are:

1. The contents of the colon are very infective, and, as during the operation the lumen of the bowel must be opened, it is almost impossible

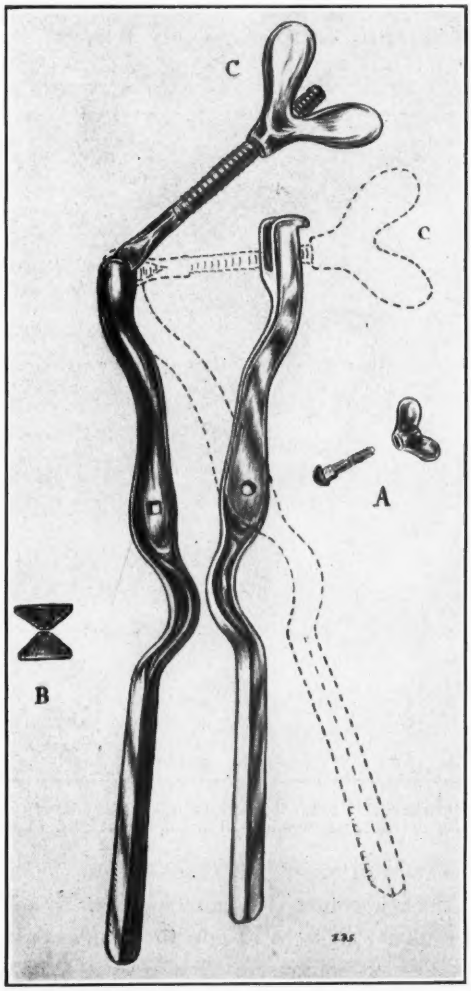

Fig. 13.—An illustration of the enterotome, with its blades disconnected. *A* indicates the screw which connects the two blades; *B*, a cross-section of the blades; *C*, the large winged nut which draws the two blades tightly together after they have been placed in position on the spur and connected.

to prevent soiling of the peritoneum and, therefore, the occurrence of some grade of peritonitis.

2. The natural vascularity of the colon is so poor that it is never certain that the cut ends of the bowel, with the added embarrassment of sutures, have sufficient circulation to ensure proper repair.

3. The repair of the peritoneal layer of the colon is not effective as in the small intestine. Infection from the colonic contents is very likely to leak to the peritoneum through the actual line of contact of the segments of bowel; it may also pass through little areas of necrosis in the cut edges of the bowel, which occur from a suture pressure in the poorly vascularized colonic wall; or it may pass along the sutures.

Wilkie recognizes the danger of making a sutured anastomosis on orthodox lines in the distal colon. Using but one layer of interrupted sutures through the seromuscular coat only, he places his sutures and ties them with great care, so to avoid any tension, and therefore any interference with the vascularity of the cut ends of the bowel.

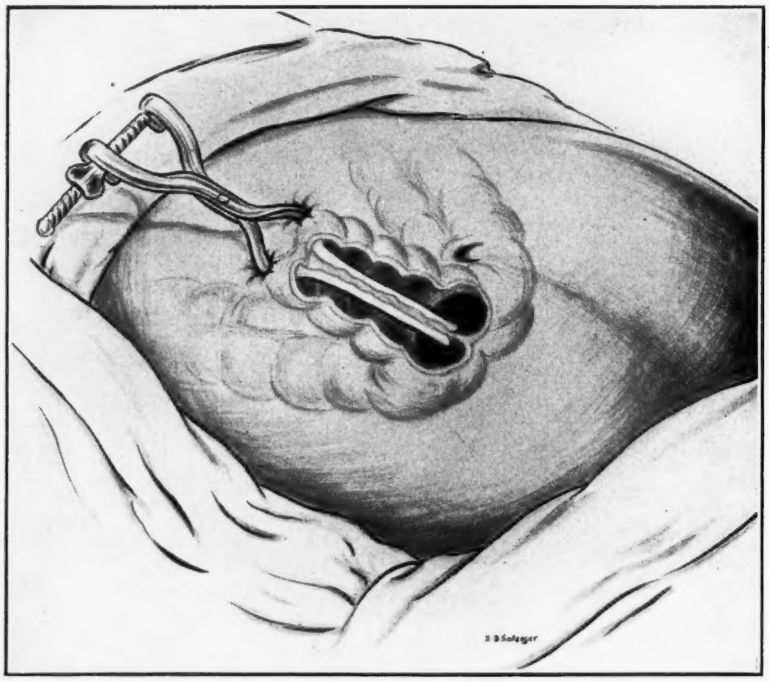

Fig. 14.—Diagram showing the enterotome applied. For diagrammatic purposes the abdominal wall in the drawing is considered transparent and the spur semisectional.

The various methods of so-called "aseptic anastomosis" cannot possibly be aseptic. Furthermore, in these methods the liability of infection along the sutures is still present and the dangers attendant on defective blood supply are not obviated. Finally, it may be accepted as a clinical fact that a sutured anastomosis made in the functioning distal colon involves a high percentage of mortality.

How Soon Should Operation Be Carried Out on the Defunctioned Colon.—The longer the distal colon has been defunctioned, the lower the bacterial content and the better the local condition. In innocent conditions, such as a diverticular tumor or the complications arising from it, operation may be delayed for twelve months. In such inflammatory

conditions, long defunctioning is sound treatment, because areas of inflammation, spreading from the tumor, resolve; and extensive adhesions, which may bind the inflammatory tumor to all the organs in its neighborhood, slowly disappear. But not only does a prolonged defunctioning of the distal colon enable the surgeon to remove inflammatory tumors, which previously were inoperable, but also it avoids for him the removal of bowel, which is inflamed, but otherwise healthy. In one patient, who developed acute intestinal obstruction as the result of an inflammatory diverticular tumor in the sigmoid, the diverticular condition completely cleared up after the distal colon had been defunctioned for twelve months, and normal function was restored to the patient. In another patient in whom I had unsuccessfully made two attempts to remove an inflammatory diverticular tumor in a defunctioned distal colon, I was able eventually, after the bowel had been defunctioned for a considerable time, to remove the tumor. Thus, in innocent affections, the longer the distal colon is defunctioned, the safer and more successful is the operation.

In malignant conditions, anyway, as far as the removal of the growth is concerned, the bowel cannot be defunctioned for more than a month. The operation for the reconstitution of the continuity of the colon can, however, be always carried out in a bowel in which a long period of defunctioning has been allowed. It is surprising to see the effect that defunctioning has on some malignant growths. In two instances where malignant tumors of the sigmoid appeared to be quite inoperable, because they were widely adherent to surrounding structures, I found that after a period of four months of defunctioning, they became operable. Only a small proportion of malignant growths, which appear to be inoperable, however, behave in this way, for it is only in a few cases that the extensive adhesions, which make them inoperable, are the result of an associated inflammatory condition arising from an ulcerating cancer tumor.

Partial Sigmoidectomy and Sutured Anastomosis in a "Defunctioned" Distal Colon.—In the defunctioned distal colon, which is quiescent, retracted, and clean, it is possible safely to perform an orthodox sutured anastomosis; and it is still possible to do so even when the segments of bowel to be anastomosed are incompletely peritonealized, or when the disparity in their caliber is great. The use of a sutured anastomosis in the case of carcinoma of the upper and lower parts of the sigmoid is of great advantage, for the requisite amount of bowel which should be removed with the carcinoma and the proper amount of pertaining mesenteric leaf can be critically estimated and then removed—an advantage which does not obtain in operations on the principles of Paul, Mikuliez, and others.

The healing of a sutured anastomosis in a defunctioned colon takes place under favorable conditions; that is, under conditions of complete rest—a most important surgical principle. The postoperative

course after these operations is uncannily uneventful—an indication of the absence of even mild grades of local peritonitis, and therefore of any degree of infection.

In the defunctioned distal colon, a real "aseptic" anastomosis can be made. This is made possible by the fact that the lumen of the "defunctioned" colon can be aseptically sealed by diathermic coagulation, and it does not matter when it opens. The method of making this "aseptic" anastomosis is illustrated in Figs. 15 and 16. The segment of bowel containing the growth is isolated with the aid of the diathermy knife and

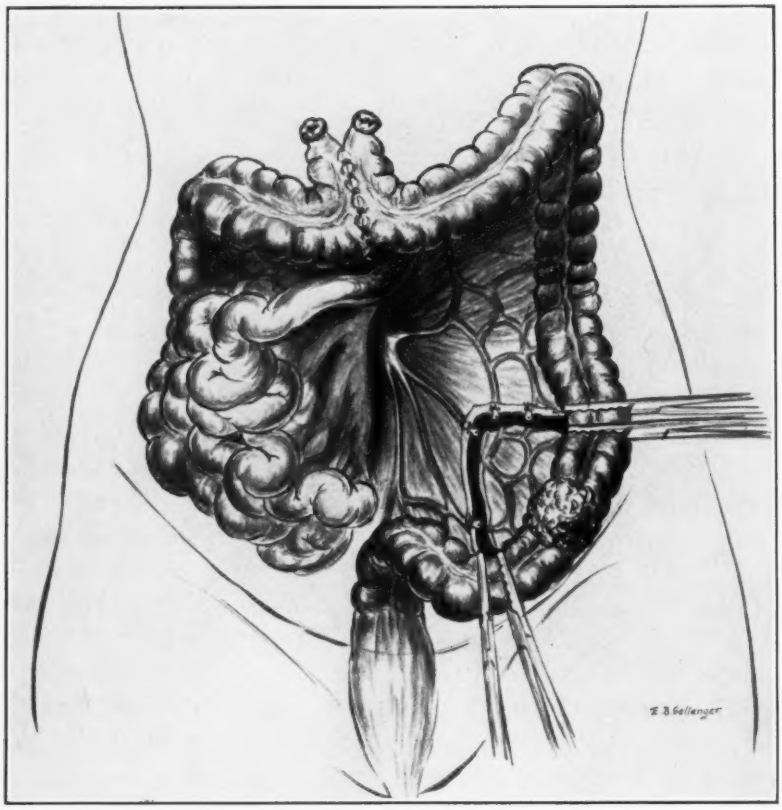

Fig. 15.—Resection of a defunctioned distal colon.

Kocher clamps, and with the corresponding part of mesenteric leaf removed (Figs. 15 and 16). The Kocher clamps closing the proximal and distal segments are then contacted with the diathermy current in order to coagulate that piece of bowel which lies within the grasp of the clamp. These forceps are then approximated as shown in Fig. 16. Interrupted sutures taking in a big bite of the seromuscular layer are now placed round the whole circumference of the bowel ends, as shown in Fig. 16. These sutures are tied so gently that the sealed ends of the bowel are not opened. The rent in the mestenry is closed in the usual way. The segment of bowel containing the anastomosis should, for additional

safety, be embedded in a little pocket of omentum. A drainage tube is inserted down to the anastomosis.

Sigmoidotomy for Removal of Single and Multiple Adenoma.—In cases where there have been large single or multiple adenomas, after defunctioning the colon for a considerable period, I have not hesitated widely to slit up the sigmoid and remove the adenoma. It is a comfort to feel that there is very little danger of a suture insufficiency in the extensively sutured sigmoid because the operation has been carried out on the defunctioned colon.

Rectosigmoid Resection With Sutured Anastomosis.—It is in growths in the lower third of the sigmoid that this method of operating on the

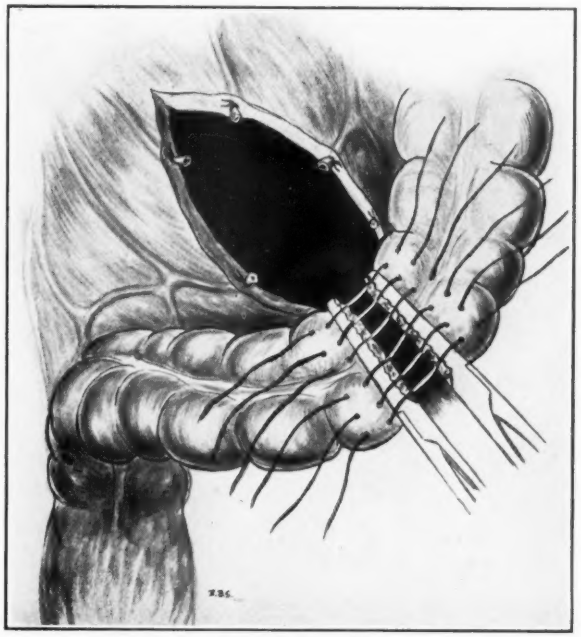

Fig. 16.—Resection and sutured anastomosis in a defunctioned distal colon.

defunctioned colon is so valuable. In this situation, any operation methods based on the principle of Paul cannot be satisfactorily carried out because they do not permit an adequate resection of the mesenteric leaf; and they do not allow sufficient removal of the bowel on the rectal side of the growth. Where, however, the operation is carried out on a defunctioned bowel, the proper amount of the sigmoid and upper part of the rectum with the corresponding part of the mesenteric leaf can be resected; and, with every prospect of success, and with very little danger, the sigmoid can be anastomosed to the divided rectum. When the repair of this rectosigmoid anastomosis takes place in a defunctioned colon, the incomplete peritonealization of the rectum does not mar the eventual successful healing of the anastomosis.

Steps in the Technique of Abdominal Rectosigmoid Resection.—The sigmoid is divided, between clamps (Fig. 17) well above the growth, and the mesentery, with its vessels, is also divided as in Fig. 15. The clamp is nearly three-quarters of an inch wide and has deep serrations so that it can get a very powerful firm grip on a piece of the cut segment. With great pressure, and the broad grip, and the coagulation of the gripped tissues by means of the diathermy current, leakage is impossible and the occluded end is absolutely sterile. This form of clamp is a convenient one for aseptically and hermetically sealing the divided ends of the colon. It can be allowed to lie uncovered in the abdominal cavity. It also serves

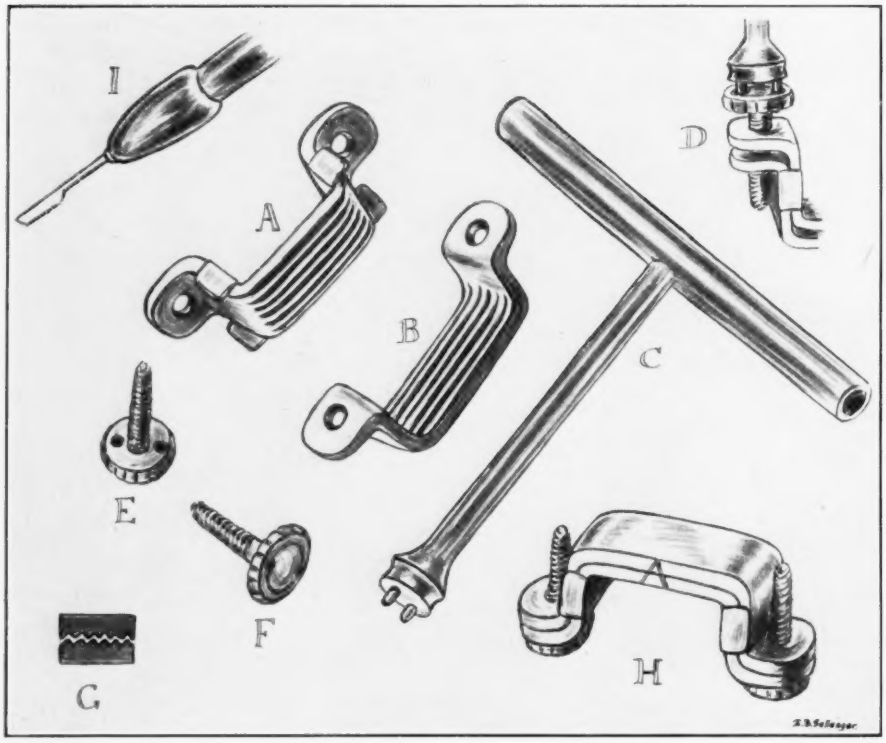

Fig. 17.—An illustration of what I call the "box clamp," which I use for closing aseptically the divided ends of the colon. *A* and *B* are the two sections of the box clamp; *C*, the key which is inserted into the screws *E* and *F* to bring the two sections of the clamp together with great pressure; *D*, the key in action; *G*, a sectional drawing which shows the serrations on the gripping surfaces of the two sides of the clamp; *H*, the box clamp assembled; *I*, the diathermy knife which is used to divide the bowel and to coagulate the cut edges of the bowel.

as a handle wherewith to make tension on the bowel when dissecting it from adhesions or out of the pelvis. Fig. 17 is an illustration of the clamp which I use for closing aseptically the divided ends of the colon.

The bowel is divided with a diathermy knife between an intestinal clamp above and a box clamp below flush with the edge of the latter clamp. The tissue at the edges of the box clamp and grasped by it is sterilized by contacting the clamp and its edges with the coagulating diathermy current. Holding the lower sigmoid segment by the box

clamp, the operator draws it forcibly upwards, puts its rectosigmoid peritoneal reflection on the stretch and divides it. The upper half of the rectum is now isolated by dissecting it from the pelvic wall laterally and from the bladder anteriorly, by means of a long spade dissecting scissors. (Fig. 18.) The rectum is divided in much the same way as the vagina is divided in the course of a panhysterectomy, and, as in this operation, a Wertheim's vaginal clamp is used to close the lower end of the rectosigmoid segment (Fig. 19). A clamp is not applied to the rectal stump

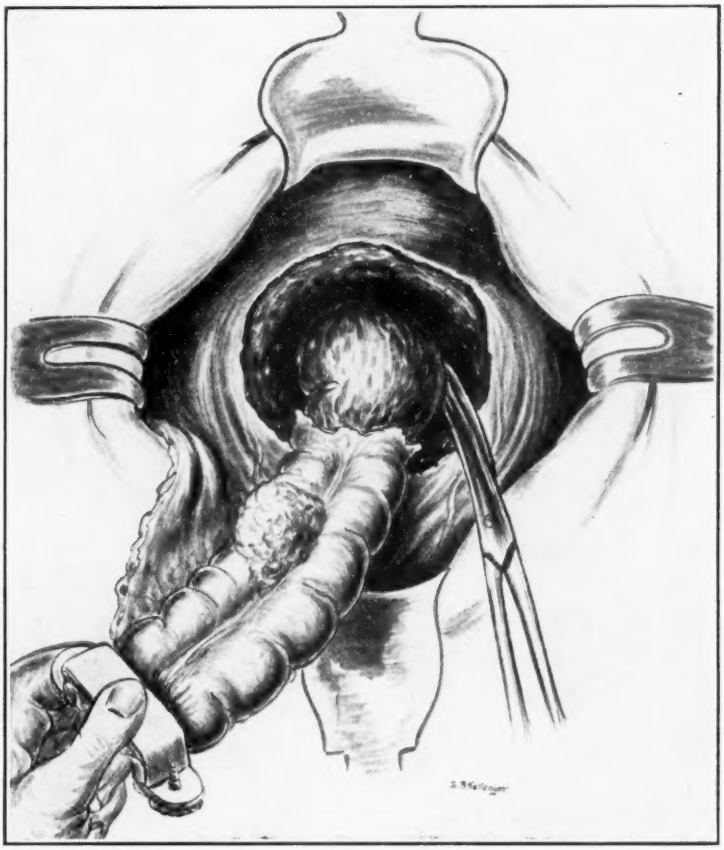

Fig. 18.—Isolating the upper half of the rectum, by dissecting it from the pelvic wall laterally and from the bladder anteriorly, by means of a long, spade-ended dissecting scissors.

because the tissue of its cut edges must not be crushed. Its use is unnecessary, as the rectum can be cleaned and sterilized, as far as it is possible, through the anus.

In the case of a woman, the tubes should be removed, because even the presence of slight infection (a mild sepsis occasionally occurs round the cut edge of the rectum) may give rise to tubo-ovarian abscesses.

The lower end of the sigmoid is now anastomosed to the stump of the rectum in the following way. The cut end of the sigmoid is examined, to make sure that it is properly vascularized. It is brought down to

the rectal stump, placed in the correct apposition to it, and secured in this position by guy-rope sutures, which, besides fixing the segments together, are used to anchor them to the operating frame. (Fig. 20.) As the bowel segments are empty and clean, interrupted sutures of fine, slightly hardened gut, taking a bite of about a third of an inch, are inserted from their lumens. These sutures are used to join the posterior and lateral walls, until it is impossible to insert any more. When this

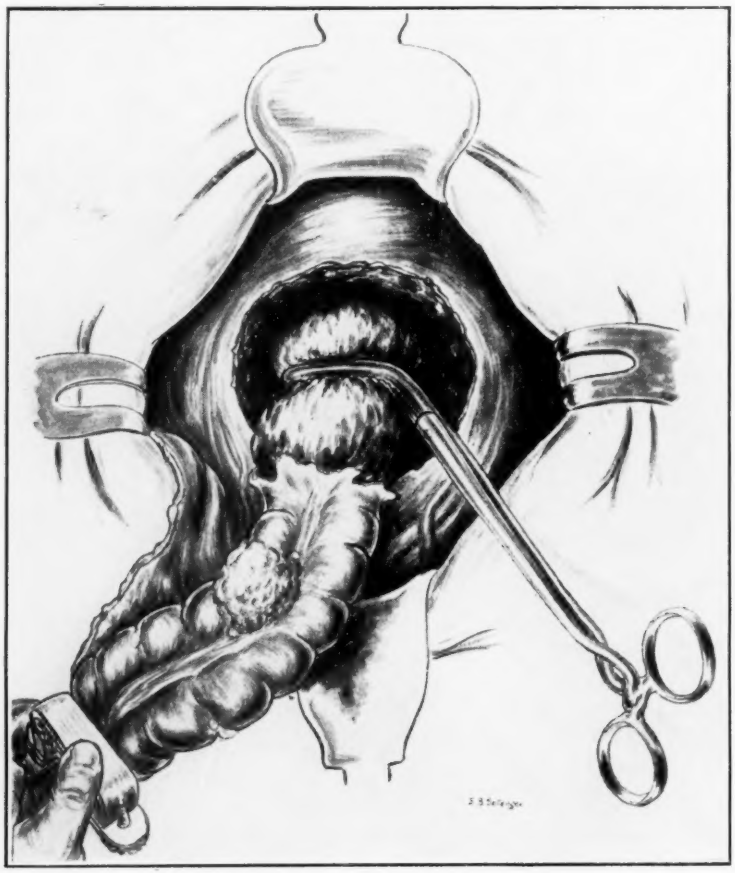

Fig. 19.—The lower end of the rectosigmoid segment is closed by a Wertheim's vaginal clamp before the rectum is divided.

point has been reached, a few figure-of-eight sutures are inserted from the external surface of the bowel in order to complete the anastomosis. (See inset Fig. 20.) Only one layer of sutures is used. The sutures are inserted from the lumen of the bowel, because on account of the cramped position it is most difficult to place the posterior layer of sutures in position from the external surface.

A long needle-holder is used to insert the sutures, and another one in the left hand serves to pick them up. By employing this double needle-holder device, it is surprising to see how deep down in the pelvis an anastomosis can be made. The pelvic peritoneum is sutured over the

anastomosis. A tube is introduced through the abdominal wound down to the anastomosis and another one is inserted through the rectum. The sphincter is divided.

About six or seven days after the operation, it will often be found that if saline solution be injected through the anus, some of it will come out of the abdominal tube. This is owing to the fact that a leak has developed in the anastomosis. The tube (or a smaller one) is therefore left in position until such time as fluid injected through the rectum shows that the anastomosis has healed. About two weeks after this, the spur of the anus is crushed.

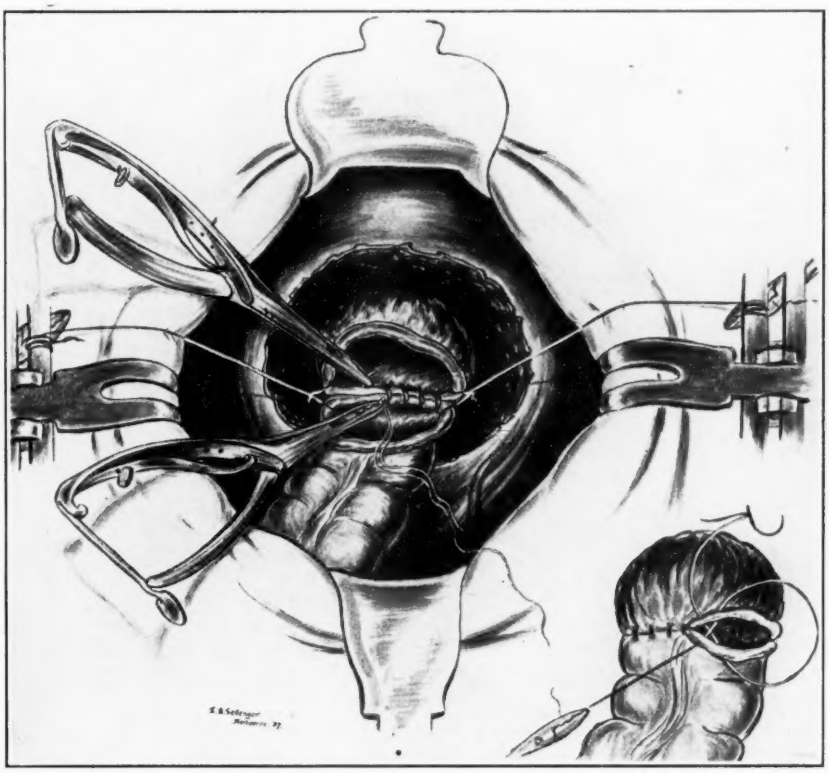

Fig. 20.—Shows, semidiagrammatically, sutures being inserted from the mucous membrane inside the bowel, so as to join the posterior wall of the divided end of the sigmoid with that of the divided end of the rectum. It also shows the use of the two needle-holders, which enable the suturing to be done in the depths of the pelvis, and how the anastomosis is guy-roped to the frame, so that in such a deep wound the ends are kept in accurate position and exact suturing is made possible. The inset shows figure-of-eight sutures being used to coapt a small section of the anterior edges of the rectum and colon segments.

As the rectum is very wide, where it is divided, and as the cut end of the sigmoid can be widened by a vertical cut, the anastomosis is rather easier to make than would be expected.

A sutured rectosigmoid anastomosis is particularly applicable after rectosigmoid resection for a diverticular tumor.

"Telescopic" Rectosigmoid Anastomosis.—In some cases of rectosigmoid resection, a sutured anastomosis between the sigmoid and the

stump of the rectum cannot be made because of mechanical disabilities. This happens in fat people, in males with narrow pelves, in the case of a small or short rectal stump. In circumstances such as these, the rectal stump may be closed as shown in Fig. 21, the peritoneum sutured over it, and the divided end of the sigmoid implanted into the abdominal wall. Then at a later stage, when the peritoneum has become "glued" on to the rectum (Fig. 22), the sigmoid may be disconnected and drawn through an opening, which is made in this rectal pouch, the sphincter of which is divided. Fig. 23 shows diagrammatically the cut end of the sigmoid

Fig. 21.—Closure of the rectal stump after a rectosigmoid resection. *A*, the sutures closing the peritoneum over it; *B*, the sutures closing the stump of the rectum; *C*, the subperitoneal space left between the sutured stump and the peritoneum; *D*, is the anus.

telescoped into the rectal pouch. A few sutures connect the peritoneum of the sigmoid to the peritoneum covering the rectal pouch, so that, as the sigmoid is drawn down, peritoneal surface becomes applied to peritoneal surface. A slotted tube (*B*), fixed in position with a safety pin, is used to keep the anastomosis in position and to drain the rectal pouch.

As the sigmoid is functionless and the rectum patulous from the division of the sphincter ani, there is no more danger from this "telescopic" operation than from drawing the sigmoid on to the surface of the abdominal wall to make an ordinary abdominal artificial anus.

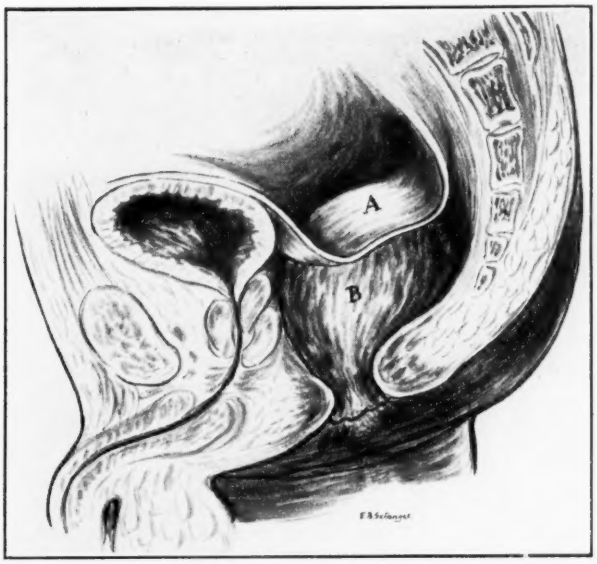

Fig. 22.—Diagrammatic (sectional) representation of the condition a month later. The peritoneum (*A*) is now shown adherent to the rectal stump (*B*) and there is no peritoneal space to admit of dangerous spreading subperitoneal cellulitis.

Fig. 23.—Shows diagrammatically the cut end of the sigmoid telescoped into the rectal pouch. A few sutures connect the peritoneum of the sigmoid to the peritoneum covering the rectal pouch, so that, as the sigmoid is drawn down, peritoneal surface becomes applied to peritoneal surface. *A* indicates ring of skin around artificial anus sutured to rubber tube; *B*, slotted tube fixed in position with a safety pin, used to keep the anastomosis in position and to drain the rectal pouch; *C*, gauze and safety pin preventing the tube from going up.

A difficulty, however, in this method is that, sometimes, it is difficult to make the opening in the rectal pouch, because the bladder falls over and adheres to the rectal stump.

The method is particularly applicable to bad cases of carcinoma of the lower end of the sigmoid; for the making of the telescopic anastomosis can be delayed for six or twelve months, when the patient will have greatly improved in health as a result of the removal of the malignant growth and when the circulation of the rectal stump—which is sometimes disturbed in these cases—will have improved.

CASE HISTORIES TO SHOW VALUE OF SUTURED RECTOSIGMOID ANASTOMOSIS ON DEFUNCTIONED COLON

CASE 1.—An old and very debilitated man with carcinoma of the lower end of the sigmoid, acute intestinal obstruction, and a late stage of diabetes. *Stage 1.*—Disconnecting anus in the proximal transverse colon. *Stage 2.*—Rectosigmoid resection with closure of the rectal stump and implantation of lower cut end of sigmoid into loin. *Stage 3.*—Six months later—resection of sigmoid mucous-fistula (artificial anus) and anastomosis by suture of lower end of sigmoid with rectal stump. Recovery: lived three years.

CASE 2.—Female, aged fifty years; diverticular tumor, intestinal obstruction. *Stage 1.*—Disconnecting anus in the distal part of transverse colon and exploration of the abdomen. Large adherent mass filling the whole of the pelvis. Regarded as an inoperable carcinoma of the sigmoid. *Stage 2.*—Three months later, at a second operation, further scrutiny of the mass now gave the impression that it was an inflammatory diverticular tumor, and not a carcinoma, as at first thought; but it was, however, still irremovable. *Stage 3.*—Six months later, at a third operation, it was found that, as the result of six months defunctioning of the distal colon, the tumor of the sigmoid had become so much smaller and less adherent that it now appeared possible to remove it; and the whole of the lower two-thirds of the sigmoid, which was involved in the tumor mass and widely adherent to adjacent structures, was removed. The severed end of the sigmoid was anastomosed to the upper part of the rectum. The patient recovered with complete function. Fig. 24 is an x-ray, made six months after the operation, of a barium clysma in this patient.

CASE 3.—Patient, aged seventy-five years, male, greatly debilitated, carcinoma of the lower end of the sigmoid, acute intestinal obstruction with great distention. *Stage 1.*—A disconnecting anus was made at the hepatic flexure (the transverse colon was short owing to the great distention), a loop being made by suturing the proximal limb of the transverse colon to the ascending colon. Exploration revealed the fact that the patient had a sigmoid growth, which, because it was adherent to the surrounding structures including the bladder, appeared to be inoperable. Two weeks later, the patient developed complete prostatic obstruction and became uremic. *Stage 2.*—Cystotomy: the bladder was connected to a continuous suction apparatus. *Stage 3.*—Some time later: prostatectomy. *Stage 4.*—Four months later: Exploration showed a small contracted distal colon and the growth now lying quite free, except for a slight attachment to the bladder, and apparently quite operable. A rectosigmoid resection was carried out and an immediate single layer sutured anastomosis made, the union being between the upper third of the rectum and the lower end of the upper third of the sigmoid. Notwithstanding the patient's great weakness and long illness, this operation did not disturb his general condition in the slightest or the function of his colostomy. He recovered from the effects of the operation, but died two months later.

These cases, illustrating as they do, the most difficult surgical problem involved in carcinomas or in diverticular tumors of the lower end of the sigmoid and the rectosigmoid junction, show the particular application of the abdominorectosigmoid resection method. They also show the lenity of the operation, since it was employed in the these very old and very sick people.

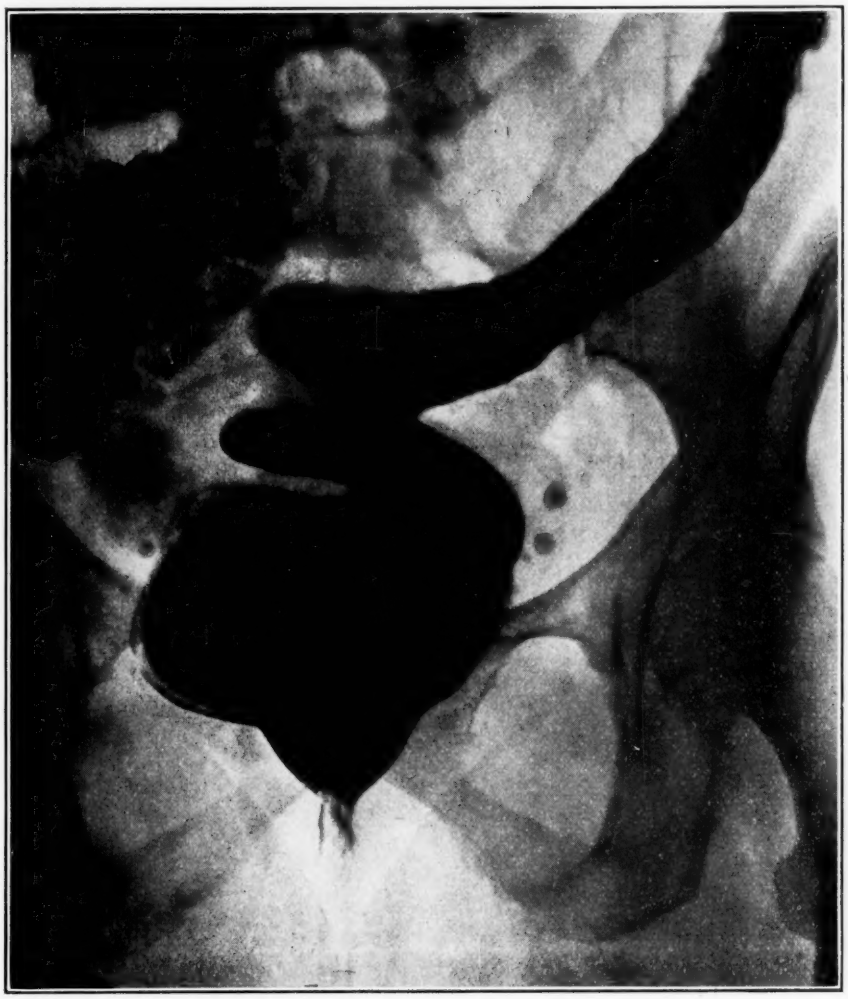

Fig. 24.—X-ray of a case in which a diverticular tumor involving most of the sigmoid was removed, and the divided end of the sigmoid anastomosed to the upper part of the rectum. (From Brit. J. Surg.)

CASE HISTORIES TO ILLUSTRATE TELESCOPIC METHOD OF RECTOSIGMOID ANASTOMOSIS

The two following brief case histories—Cases A and B—illustrate the uses of this telescopic method of rectosigmoid anastomosis:

CASE A.—A very fat man, aged fifty-six years, a hotel keeper, developed acute intestinal obstruction. He was operated on in the country, and what appeared to be an inoperable carcinoma of the sigmoid was found. In order to relieve the obstruction, an artificial anus was made in the upper end of the sigmoid.

Subsequent investigation by me created the suspicion that the tumor was inflammatory and that it was the result of an extensive diverticulitis.

At a second operation, the whole of the sigmoid, including the portion bearing the artificial anus, was removed. It was impossible to approximate the divided ends of the bowel and therefore to make an anastomosis. Consequently it was necessary to close the divided rectum by suturing separately the muscle layer and the peritoneum (shown in Fig. 21) and also to implant the distal cut end of the beginning of the sigmoid into the loin, where it would function as an artificial anus.

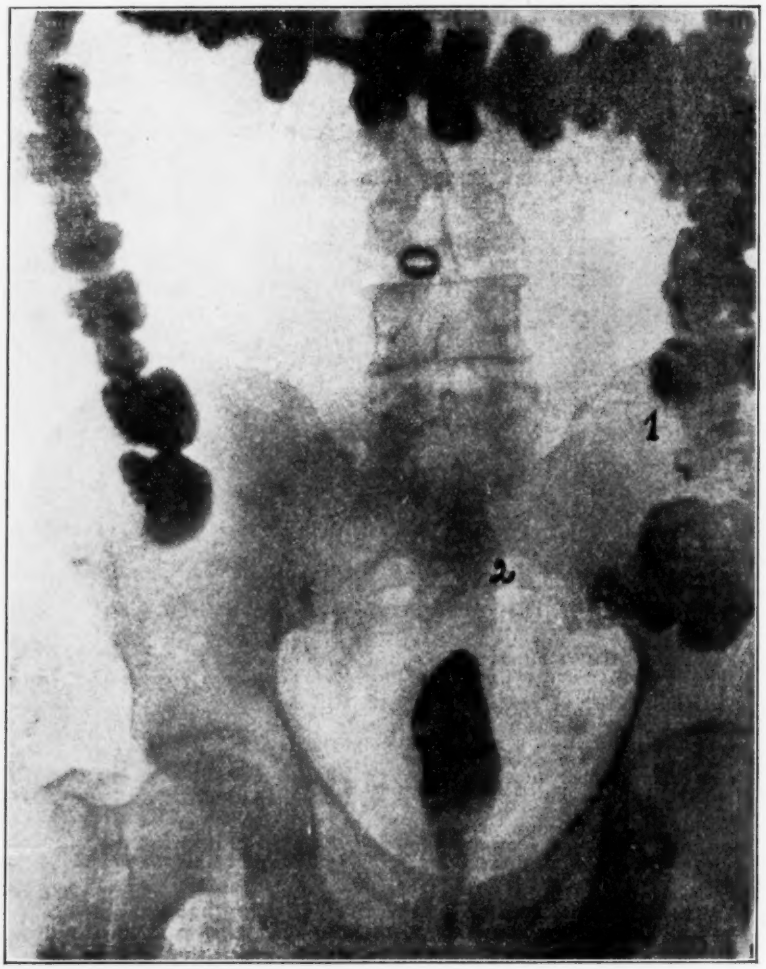

Fig. 25.—Skiagram of the descending colon and the rectal stump in this case. After four years the distal end of the descending colon had elongated a little from the increased function imposed on it. Note the smallness of the rectal stump. *1* is the lower end of descending colon; *2*, the stump of rectum. (From Australian & New Zealand J. Surg.)

Four years later, at the request of the patient, who could not any longer tolerate the artificial anus, I decided to make an attempt to unite the descending colon to the rectum. The skiagram (Fig. 25) shows the level of the division of the sigmoid—almost at its beginning—and the smallness of the rectal stump.

After making a disconnecting anus in the manner already described and preparing the distal colon, the sigmoid was joined to the rectal stump by a telescopic anastomosis made in the way which has been described (Fig. 23).

The following are the detailed steps of the operation: (a) The abdomen was opened by a median subumbilical incision; (b) an incision was so made round the artificial anus that a substantial ring of skin was left attached to the mucous membrane; the anus was then disconnected from the abdominal wall and the descending colon extensively mobilized; (c) a rubber tube 2.5 cm. (1 inch) in diameter, cut as shown in Fig. 23 was now sutured to the ring of skin which had been left attached to the artificial anus for this purpose. (d) A sponge holder with a swab on the end was now introduced through the anus into the rectum and pressed against its upper blind end. An incision 3.75 cm. (1½ inches) long was made through the rectal wall. The forceps was now made to grip the end of the tube and draw it, with the attached bowel, through into the rectum.

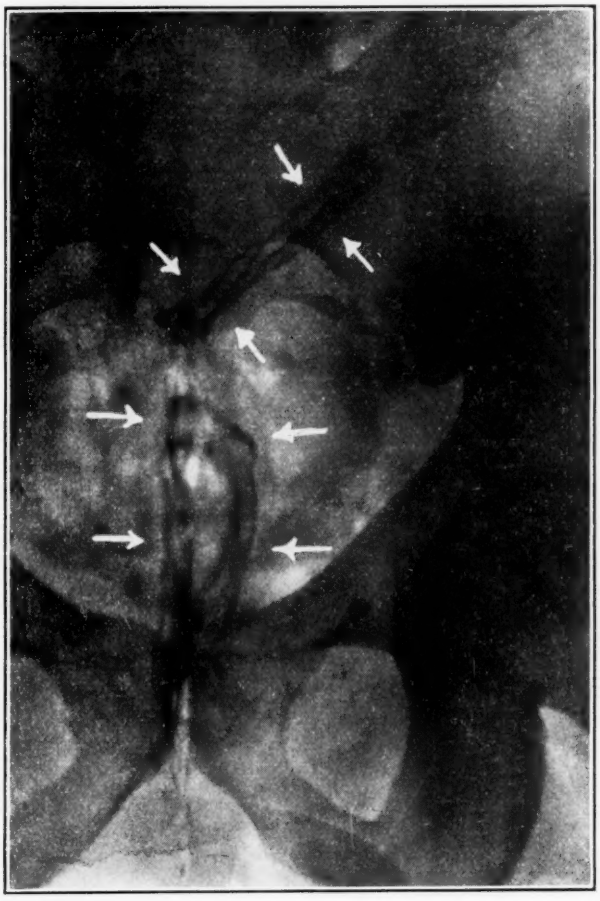

Fig. 26.—An x-ray picture of the rectum of this patient, made after a barium clysma followed by injection of air. It was taken four years after the "telescopic" operation. Note the straight tubelike rectocolic segment. (From Brit. J. Surg.)

The rectal stump had contracted from disuse, and, as the patient was very fat, a tunnel had therefore to be made posteriorly to the bladder before the rectum could be incised. Consequently, when the bowel was drawn through this tunnel, there was no space whatever which would permit the manipulations required for the insertion of sutures in order to unite the cut edge of the rectal wall to that of the colon. Union of the bowel ends was then attained as follows: (e) The obliquely cut part of the tube was drawn down through the anus and kept in this position by means of gauze and a very large safety pin inserted as shown in Fig. 23. The sphincter grasping the obliquely cut part of the tube prevented the tube from

moving downward. The safety pin prevented it from going upward. The bowel ends were therefore held in position in which they were placed. The slotted part of the tube drained any contents which might have accumulated in the rectal cavity. A drainage tube was introduced abdominally down to the junction of the colon with the rectum.

The convalescence of the patient was uneventful. Four weeks after the operation, when it was found that the anastomosis was firmly healed, a little local anesthetic was injected into the small strip of skin between the bowel ends and the spur of the midcolic anus was crushed. The artificial anus then closed naturally in a very short time. Four years later, an x-ray (Fig. 26) showed that this patient was functioning perfectly and that no contraction had taken place at the telescopic union.

CASE B.—A female, aged fifty-five years, who had a carcinoma of the lower end of the sigmoid, was operated on in the following stages: *Stage 1.*—Disconnecting anus made at the proximal part of the transverse colon, when an exploration revealed a carcinoma situated close to the lower end of the sigmoid.

Stage 2.—Three weeks later: Resection of the lower end of the sigmoid and the upper part of the rectum, closure of the rectum, and implantation of the cut end of the sigmoid into the abdominal wall. *Stage 3.*—Many months later when the patient was in good health: mobilization of the upper part of the sigmoid and the descending colon, and the making of a telescopic anastomosis with the rectal pouch, the sphincter ani of which was divided. This patient is now well and has functioned normally for sixteen months.

RESULTS

The case histories quoted are only a few examples out of many of the type of cases in which, with no other method, I could achieve the same results. So far, the series of patients on whom I have operated by the defunctioning method is not yet extensive enough to make generalizations. The immediate results in the patients on whom I have operated by this method, however, even in the most difficult cases, have been so successful and show so clearly the great potentialities of operating by this principle, that surgery of the distal colon has no longer, for me, the anxiety that it formerly held.

In cases in which a sutured anastomosis was made on the "defunctioned" colon, the convalescence of the patients was remarkably quiet and the abdominal cavity manifested no reaction of any sort. In one operation which involved the removal of a large carcinoma of the transverse colon adhering to an abdominal scar and also that of a segment of small intestine, the subsequent convalescence was so smooth and so free from reaction that one could not but be struck with the very great advantage of these operations on the "defunctioned" colon.

I have been able to unite the sigmoid to the rectum in a very debilitated patient who suffered from diabetes, and who came into hospital with acute intestinal obstruction; to join up, under very adverse circumstances, the upper part of the sigmoid to the lower two-thirds of the rectum—and without using a single suture; to remove growths of the sigmoid which at the first approach were inoperable; and to slit up the sigmoid and remove single and multiple adenoma. I feel, therefore, that a method of operating, which has such potentiality for cure in the bad cases, is a method which might well be the surgeon's choice for routine colon surgery.

ACUTE CHOLECYSTITIS

Problems Created by an Attempt to Correlate Its Clinical, Surgical, and Pathologic Manifestations

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In 1928, H. O. Bruggeman concluded a paper, in which were quoted the views of the leading surgeons of this and other countries with regard to the treatment of acute cholecystitis, with the following statement: "I wish to express the hope that some day surgeons will be fairly unanimous in their views on the treatment of acute inflammation of the gallbladder." That hope is, if anything, further from fulfillment today than it was at that time.

It is not the purpose of this paper, however, to express a dogmatic opinion in regard to this highly controversial subject, nor to argue the case for immediate, early, or delayed operative treatment of acute cholecystic disease. Our purpose is to consider some of the problems created by an attempt to correlate the clinical, surgical, and pathologic manifestations of the disease, and, since at present there is no uniformity of opinion among surgeons as to what constitutes immediate, early, or delayed treatment, to raise the question whether there ever can be, because of the nature of the disease.

The advocates of each of these schools seem to stand firm in the belief that theirs is the proper method of treatment, and furthermore each group believes there is good evidence to substantiate its arguments. As a consequence, confusion has increased. "Immediate," for example, may mean that operation was performed within a few hours after the onset of the attack of cholecystitis. In such cases the patient is admitted to a hospital and is immediately operated upon. Indeed, patients with acute cholecystitis are sometimes subjected to an exploratory operation in the incipient stages of the disease because the condition has been mistaken for ruptured ulcer or acute appendicitis. Protagonists of this school claim that these patients as a group do well. As a rule, they are operated on when they are still in good general condition, before they become dehydrated from prolonged vomiting or anorexia, and while the acute process is localized to the site of origin and before it involves the pericholecystic tissues and biliary passages. At this time, too, one is not so often called on to combat hemorrhage from friable, edematous, or indurated structures,

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with possible injury to the common duct or the hepatic blood supply. The good results said to have been obtained in such cases and the low morbidity and mortality recorded have undoubtedly brought about the recent wave of enthusiasm for "immediate" operation in cases of acute cholecystitis.

"Immediate" operation, however, is also applied not only to cases in which patients are operated on soon after their arrival in a hospital, but also to cases in which such patients may have suffered an attack of acute cholecystitis for several days before admission. Usually these are cases in which the patient has been guilty of procrastination, or in which the original attending physician has instituted conservative treatment as a primary procedure. Such patients are, as a rule, in poor condition for operation and the technical difficulties are increased at the time of surgical intervention. It is operations in this type of case which cause the advocates of "delayed" treatment to view with some apprehension the teaching of those who advise prompt surgical intervention. For example, Zinninger reported the results obtained by "immediate" (on the patient's admission to the hospital) operation in 35 cases. In 12 of these cases the duration of the attack was less than forty-eight hours. There were no deaths in the group. In 15 cases the attack had lasted for from two to five days. One of these patients died, giving a mortality of 6.6 per cent. In 8 cases immediate operation was performed after the patient had been sick for five or more days at home. Of these patients 2 died, or a mortality of 25 per cent. While this series is small, at least it shows a trend of possible significance.

Confusion is also caused by the fact that authors speak of "early" operation without a uniform definition as to what they consider early to be. To one, "early" may mean operation within thirty-six hours after the onset of the attack; to another it signifies operation within five days of the onset of acute symptoms; and to a third, cases in which operation is performed at a later period may still fulfill the requirements of early operation. On the other hand, at least one defender of the "delayed" treatment of acute cholecystitis said that he believed that the best policy was to hospitalize the patient for two, three, or four days, or longer, after the onset of the attack before surgical intervention was contemplated, depending on the clinical picture present in the individual case. It seems reasonable to believe, therefore, that there is some duplication of material among those who are advocating "early" and "delayed" treatment.

There are so many variable factors involved in a consideration of acute cholecystitis that it is frequently difficult to tell not only the time of onset of the acute attack, but also the duration of the acute phase. These variables may include, among many others, the presence or absence of an infecting organism and its virulence if one is

present, the presence or absence of stones, the number of previous attacks, general and local tissue resistance, and the acuteness and degree of the interference with the blood supply to the gallbladder. It is well known that after the acute clinical signs in the right upper abdominal quadrant have subsided, and when the pulse rate and temperature have returned to normal, the operative and histologic picture may remain that of acute cholecystitis. In fact, one of the most interesting features of biliary disease, as W. J. Mayo has so frequently pointed out, is the impossibility in many instances of correlating the clinical picture with the degree of inflammation in the gallbladder. It is therefore conceivable that the results of operation reported for a series of cases in which a definite pathologic diagnosis of acute cholecystitis has been made might be radically different from those reported for a group of cases in which the clinical signs and symptoms alone have been the basis of the diagnosis.

Is the diagnosis of disease of the gallbladder to be based on the clinical, surgical, or pathologic findings? In few other diseases are the clinical and the pathologic diagnoses so likely to be at variance. This fact has been emphasized also by Andrews, Heuer, and others. Cases in which a clinical diagnosis of acute cholecystitis has been made may fail to show evidence of the acute process on pathologic examination; and, conversely, cases in which inflammation in the gallbladder is considered from a clinical standpoint to be chronic not infrequently give evidence of acute or subacute disease histologically. How often does this occur? In an effort to clarify our own thought on these questions, we have reviewed the recent literature on the treatment of acute cholecystitis and have examined the histories in a consecutive series of cases of cholecystitis of all types in an effort to correlate the clinical, surgical, and pathologic findings.

A group of 200 consecutive cases of cholecystic disease of all types, in which cholecystectomy was performed and microscopic sections were studied by Dr. A. C. Broders, was used as the basis for the following studies. The clinical, surgical, and pathologic diagnoses were noted in all cases (Table I). In 176 cases, for example, a clinical diagnosis of chronic cholecystitis had been made, but only 129 (73.3 per cent) of these cases were classified as being chronic cholecystitis by the surgeon at the time of operation. In 46 of these cases (26.1 per cent) the surgical diagnosis was subacute cholecystitis and 1 case (0.6 per cent) was called acute cholecystitis. The pathologist, after gross and microscopic inspection, corroborated the diagnosis of chronic cholecystitis in only 100 cases (56.8 per cent). In 72 cases (40.9 per cent) the condition was found by him to be subacute cholecystitis superimposed on a chronic cholecystitis, and in 4 cases (2.2 per cent) he found acute cholecystitis to be present. The remaining data are given in Table I.

These figures serve to emphasize the frequent difficulty of accurate clinical diagnosis of the degree of inflammation present in the individual case of cholecystitis.

TABLE 1

CORRELATION OF CLINICAL, SURGICAL, AND PATHOLOGIC DIAGNOSIS IN 200 CASES OF DISEASE OF THE GALLBLADDER

CLINICAL DIAGNOSIS	CASES	SURGICAL DIAGNOSIS						PATHOLOGIC DIAGNOSIS					
		CHRONIC CHOLECYSTITIS		SUBACUTE CHOLECYSTITIS		ACUTE CHOLECYSTITIS		CHRONIC CHOLECYSTITIS		SUBACUTE CHOLECYSTITIS		ACUTE CHOLECYSTITIS	
		CASES	PERCENTAGE	CASES	PERCENTAGE	CASES	PERCENTAGE	CASES	PERCENTAGE	CASES	PERCENTAGE	CASES	PERCENTAGE
Chronic cholecystitis	176*	129	73.3	46	26.1	1	0.6	100	56.8	72	40.9	4	2.3
Subacute cholecystitis	17	3	17.7	10	58.8	4	23.5	3	17.6	13	76.5	1	5.9
Acute cholecystitis	6	0	0	4	66.7	2	33.3	1	16.7	4	66.6	1	16.7

*In 1 additional case primary carcinoma of the gallbladder was present.

In the majority of cases the total leucocyte count is an unreliable aid in determining the degree of inflammatory reaction present in cholecystic disease. The presence of residual, localized, right upper quadrant tenderness of even a slight degree, however, should lead one to suspect that subacute cholecystitis may be present, although our studies indicate that this sign is also unreliable; when present, its interpretation is rendered difficult by the variation in the reaction of individuals to pain.

In 174 of the 200 cases in this group the Graham-Cole test was performed. The gallbladder was shown roentgenographically to be poorly functioning or to be nonfunctioning in 71.8 per cent of these cases. The test, however, was of little value in distinguishing the chronically from the subacutely, inflamed gallbladder. However, in the 5 cases of pathologically acute cholecystitis in which the dye excretion test was carried out, in not one was there normal function.

Bannick has recently emphasized the value of the blood sedimentation rate in following the progress of cases of acute cholecystitis. For those who desire to wait until the acute process has subsided before operating, it would appear to be a more sensitive index than the total leucocyte count, the pulse rate and temperature, or the degree of tenderness. Furthermore, failure of the sedimentation rate to return to normal after a proper trial of conservative management may indicate impending rupture or gangrene of the gallbladder and the necessity for surgical intervention.

COMMENT

The question that obviously suggests itself is whether there can ever be any uniformity in the treatment of acute cholecystitis, and furthermore, if such uniformity is desirable? Is there necessarily only one way for all surgeons to treat all patients with acute cholecystitis? Can so complicated a disease be reduced to such simple terms as "hours after onset," or "delayed," "early," or "immediate" operation? In view of the many variable factors that may complicate the individual case, it hardly seems reasonable to believe that it can.

We have attempted to show the difficulties and uncertainties of accurate clinical diagnosis. In the final analysis, however, it appears that no rule of thumb can ever substitute efficiently and effectively for sound surgical judgment in the management of the individual case in which there is an acute inflammatory process in the gallbladder.

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A RECONSTRUCTION OPERATION FOR DIASTASIS RECTI

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A SATISFACTORY technique for the reconstruction of the abdominal wall in diastasis recti provides for the transplantation of the rectus muscles to the midline with minimum injury to the nerve or blood supply, satisfactory fixation of the muscles in this position, narrowing of the rectus sheaths, and adequate strengthening of the fascia in the intermuscular area. The method described below satisfactorily meets these requirements.

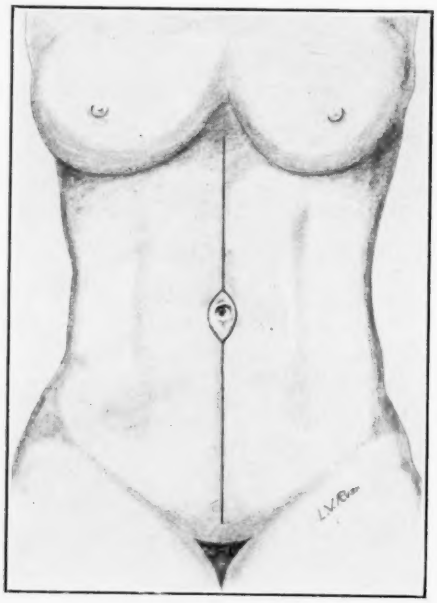

Fig. 1.—The incision.

TECHNIQUE OF THE OPERATION

A midline abdominal incision is made, beginning at the xiphoid process and extending downward to the symphysis pubis, excising the umbilicus (Fig. 1).

The anterior sheath of each rectus muscle is opened in its entire length at the medial border, resulting in two parallel incisions just lateral to the linea alba (Fig. 2). The fascia of the anterior sheaths is dissected laterally on either side and the rectus muscles gently freed from their beds by blunt dissection, care being exercised to protect the nerves and blood vessels.

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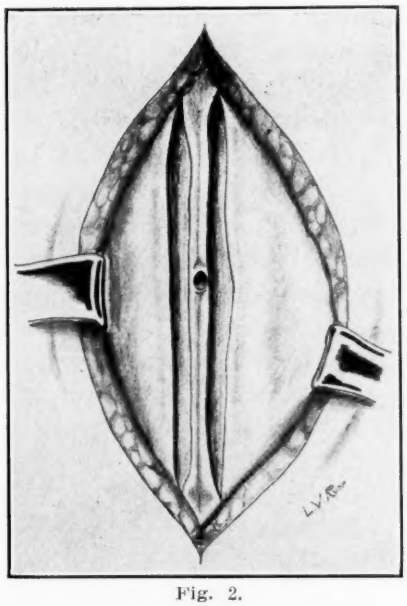

Fig. 2.

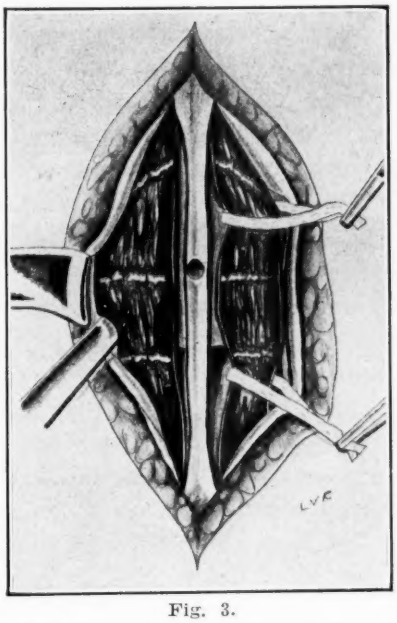

Fig. 3.

Fig. 2.—The umbilicus has been excised and the sheaths of both rectus muscles opened near the midline.

Fig. 3.—The left rectus muscle has been freed and is surrounded by loops of beef fascia. The right rectus muscle is being freed by blunt dissection.

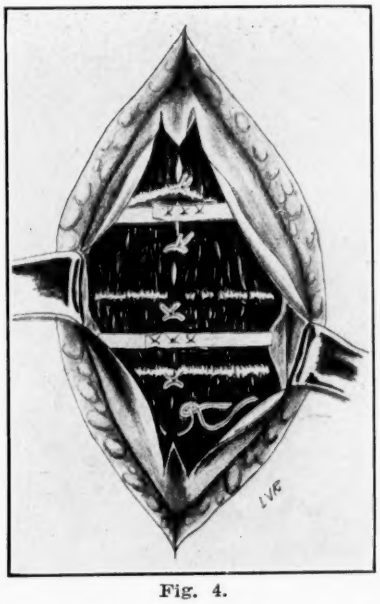

Fig. 4.

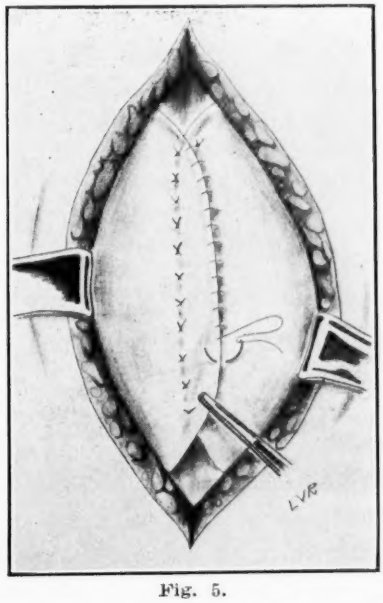

Fig. 5.

Fig. 4.—The fascia loops have been sutured on the anterior surface of the muscles retaining them in their new position without tension. The medial borders of the muscles have been approximated with interrupted No. 0 chromic sutures.

Fig. 5.—Interrupted mattress sutures of No. 1 chromic catgut have been placed, the fascia is overlapped with running sutures of No. 0 chromic catgut.

At a point about two inches above the umbilicus level, a strip of beef fascia is passed transversely behind the left rectus muscle and a loop formed which is held by an artery forceps. This same procedure is repeated at a point about one and one-half inches below the umbilicus. (Fig. 3.) The medial end of each strip of beef fascia is then carried transversely to the right, anterior to the linea alba and posterior to the right rectus muscle.

The rectus muscles are approximated and sutured to each other in the midline by interrupted sutures of No. 0 chromic catgut. The ends of the respective strips of beef fascia are brought over the anterior surfaces of the muscles and sutured to each other with No. 0 chromic catgut, thus forming a loop to retain the muscles in their new position. (Fig. 4.) It is important that the loops be brought together not tightly enough to constrict the muscle. The anterior sheaths of the recti are then overlapped in the midline by interrupted mattress sutures of No. 1 chromic catgut. A continuous suture of No. 0 chromic catgut fixes the free border of the fascia. (Fig. 5.) The skin is closed with figure-of-eight silkworm stitches.

AFTER-TREATMENT

The patient is kept in bed for three weeks after the operation. Muscular exertion is avoided for two months. An abdominal support may be employed very wisely for several weeks after getting out of bed. After this period exercises are recommended, not only for the strengthening effect, but also to encourage a compensatory thickening of the abdominal fascia. A protuberant abdomen may result from the prolonged use of an abdominal girdle or support, due to atrophy of nonuse.

SUMMARY

An operation is described for the repair of diastasis of the rectus abdominis muscles.

1. A long midline incision is made and the umbilicus excised.

2. The muscles are dissected from their beds and retained in the midline by loops of beef fascia.

3. The muscles are approximated in the midline by interrupted sutures.

4. The fascia of the anterior sheaths of the rectus muscles is overlapped in the midline.

5. After-treatment consists of three weeks' rest in bed and use of an abdominal support for six weeks followed by active exercise.

OSTEODYSTROPHY OF UNKNOWN ETIOLOGY*

Case Report

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CASES of multiple and progressive deformities of the skeleton which do not fit into any of the recognized classifications of skeletal dystrophies are only occasionally seen. The following case of idiopathic osteodystrophy has been under observation at the University of Chicago Clinics for nine years and both the deformities and the resultant disabilities have progressed in spite of medical therapy and repeated attempts at correction by means of surgical operations.

A. K., male, aged fifteen years, was first admitted to the University of Chicago Clinics, Oct. 8, 1928, at the age of six years and eleven months, because of multiple progressive deformities and increasing difficulty in walking. He was the first-born child of parents who were first cousins. Delivery was completed with forceps after a labor that lasted for twenty-seven hours. No abnormalities were noted at the time of birth, but a few days later the mother found a small hard lump on the cranium just in front of the posterior fontanel. He was able to sit up at the age of nine months and never crawled on his hands and knees, but "scooted" along on his buttocks until he began to walk at sixteen months. From the time that he began to talk his voice was observed to be raspy and hoarse. At eighteen months of age, the valgum deformity of his knees was noted, and without a definite diagnosis he was treated with cod liver oil, phosphorus, and Fowler's solution. There was also a soft pea-sized tumor of the skin of the lower lip, a large soft tumor beneath the skin of the left flank, and a one-half by one inch-sized pigmented spot on the skin of the left side of the neck.

A bilateral tibial osteotomy was performed at the age of two years, but when weight-bearing was resumed the valgum deformity of the knees recurred. An examination at this time revealed partial occlusion of the bony canal of the left ear caused by a small exostosis with slight diminution of hearing. When he was aged about three years, curvature of the spine and a bony growth on the plantar aspect of the left calcaneus were observed. An attempt to correct the scoliosis and to straighten the legs by operation was not successful.

*This study was conducted in part by a grant from the Douglas Smith Foundation for Medical Research.
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When he was five years of age, a soft tissue tumor was observed on the sclera of the left eye at about the five o'clock position and a bony exostosis in the left supraorbital rim was noted. In January, 1928, when he was six years of age, he began to have pain in the left lower abdomen. This had recurred at intervals and was thought to have been caused by the scoliosis and vertebral exostoses. After a period of head and foot traction, osteotomies were again performed and oral administration of calcium salts was begun in addition to the cod liver oil, which had been continued since infancy.

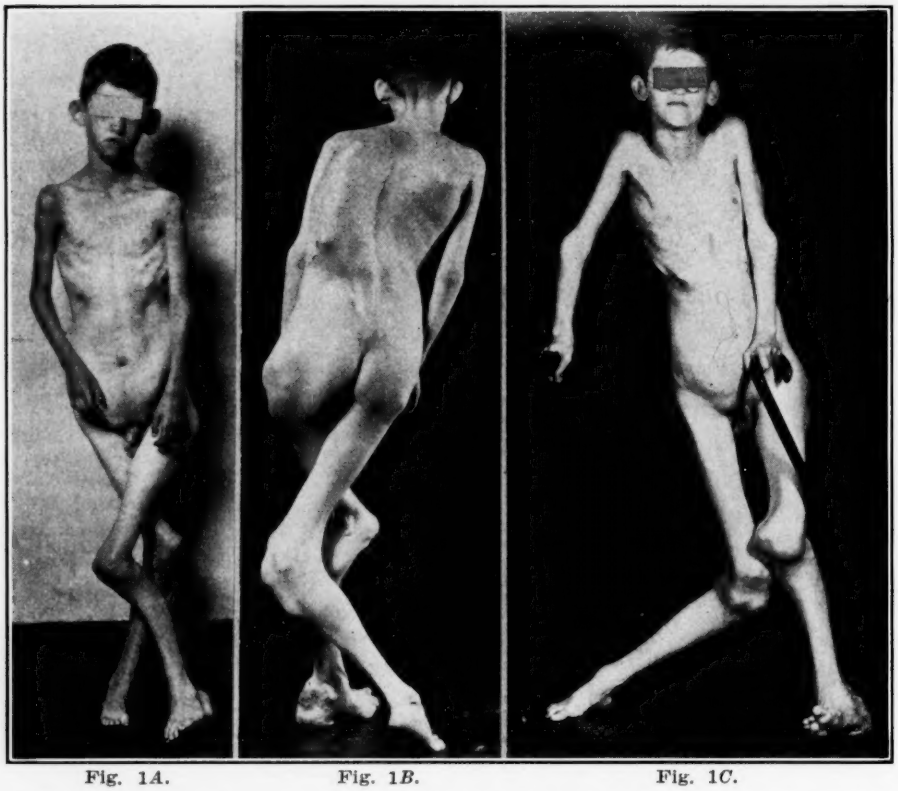

Fig. 1*A*. Fig. 1*B*. Fig. 1*C*.

Fig. 1*A*.—Appearance of the patient on admission, aged six years eleven months. The marked deformity of the lower extremities, multiple exostoses, and the rachitic rosary are shown. The apparent asymmetry in the length of the arms is caused by the scoliosis. The large lipoma of the left flank is not apparent in this photograph.

Fig. 1*B*.—May 9, 1931, aged nine years. All deformities have increased. The osseous growths on tibia, femur, pelvis, spine, and ribs and the bony tumor of the left calcaneus have grown larger.

Fig. 1*C*.—Dec. 21, 1935, aged thirteen years.

At the time of his first admission to the University of Chicago Clinics, aged six years and eleven months, his parents stated that all of the deformities had progressed in spite of the repeated osteotomies and attempts at correction. The bony growth on the plantar surface of the left foot had enlarged so that a shoe one and one-half sizes larger than the right was necessary. This mass caused some pain and made walking more difficult.

The past medical history of the patient was negative. He had complained of difficulty in swallowing and seemed to have more trouble with liquids than with solid foods. There was occasional nausea and emesis sometimes occurred immediately after eating, but no organic basis for this could be established.

The family history revealed no other instance of any type of congenital abnormality or developmental deformity. The one other child, a younger brother of the patient, is now twelve years of age, well developed and normal in every respect.

Physical Examination.—At the time of his first admission to the Clinics, physical examination showed a slender, maldeveloped white male who appeared to be older than the stated age of seven years. Both trunk and extremities were long and angular, with gross deformity of the calvarium, spine, thorax and lower extremities. (Fig. 1*A*.) The abnormal findings at this time may be itemized as follows:

Oct. 8, 1928:

1. Asymmetry of the face.
2. Three small bony prominences (exostoses) along the parietal occipital suture line and a fourth over the lateral margin of the left orbit.
3. Small raised tumor on the sclera of the left eye at about the five o'clock position.
4. Small, soft, pea-sized subcutaneous tumor on the lower lip.
5. Small bony growth on the mandible below and lateral to the left lateral incisor.
6. Hearing in the left ear slightly diminished and a small exostosis partially occluding the external canal.
7. Palpable exostoses on the right transverse processes of the fifth and sixth cervical vertebrae.
8. Loss of normal cervical curve and loss of motion in cervical spine.
9. Brown pigmentation of the skin area 1.5 by 3.5 cm. on the anterolateral surface of the left side of the neck. A similar, but smaller area of pigmentation was present over the back of the left scapula.
10. Flat chest; pot belly; beading of the ribs at costochondral junctions.
11. Marked scoliosis of the spine and deformity of the sacrum.

TABLE I

DATE	BLOOD SERUM				
	CALCIUM	PHOSPHORUS	CO_2 CONTENT	pH	PRODUCT OF Ca AND P
1929	MG. PERCENTAGE	MG. PERCENTAGE	VOL. PERCENTAGE		
Aug. 17	11.70	4.85	59.30	7.61	56.8
Aug. 20		5.71	61.8	7.57	
Aug. 22		5.924	69.4	7.55	
Aug. 26	11.6	4.76	57.2		55.4
Aug. 28	12.21	5.51	63.8	7.57	67.4

DATE	URINE			REMARKS
	VOL. 24 HOUR	SPECIFIC GRAVITY	CALCIUM	MG. PER 24 HOURS
Aug. 22	700 c.c.	1.020	105.7	On Ca balance diet
Aug. 27	590 c.c.	1.022	91.76	Regular hospital diet

12. Soft, freely movable subcutaneous tumor in the left flank, 8 by 5 by 2 cm.

13. Large, irregular exostoses over the left hip joint and greater trochanter.

14. Bilateral knock knee deformities with large irregular exostoses on the condyles of both femurs and tuberosities of the tibias and on the right patella.

15. Deformity and irregular exostosis of os calcis and tarsals of the left foot.

16. Hard, firm, opaque mass 1 cm. in diameter in the upper portion of the left epididymis.

17. Scars of previous osteotomy operations over femurs and tibias.

18. The upper extremities were thin but presented no gross abnormalities or osseous deformities.

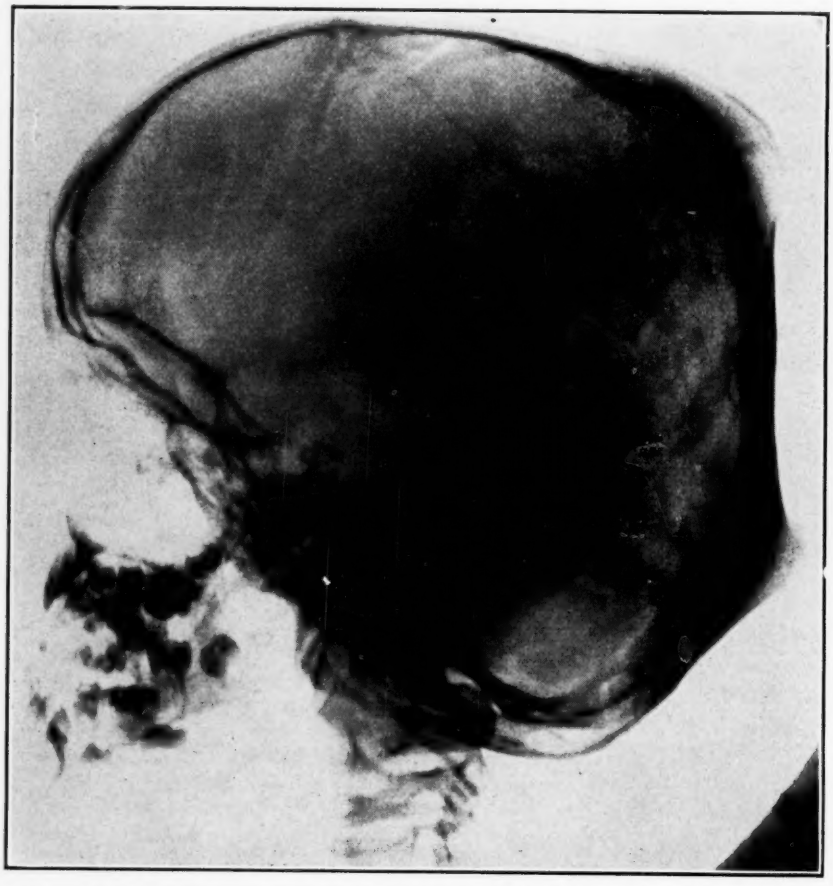

Fig. 24.—Roentgenogram at age of seven years. This lateral view shows two large osteomas of the outer table of the calvarium.

Progression of the deformities is shown in Fig. 1, *B* and *C*. The blood Wassermann and Kahn tests were negative. Hemoglobin was 60 to 65 per cent.

Because of the pigmented areas, the multiple soft tissue tumors and the extensive osseous involvement, a tentative diagnosis of von Recklinghausen's neurofibromatosis was made. Examinations of portions of the bony tumors excised at the time of subsequent attempts to correct the deformities by osteotomy failed to show the microscopic picture of neurofibromas.

In August, 1929 (Table I), analyses of the blood serum showed normal calcium, phosphorus, and carbon dioxide with a slight shift of the hydrogen ion content toward the alkaline side. The excretion of calcium and phosphorus in the urine was also found to be within normal limits. These determinations have been repeated at subsequent admissions but have never been found to be abnormal.

Roentgenographic Examinations.—These have been made at intervals during the past seven years and have revealed progressive enlargement of the previously described bony excrescences and exostoses.

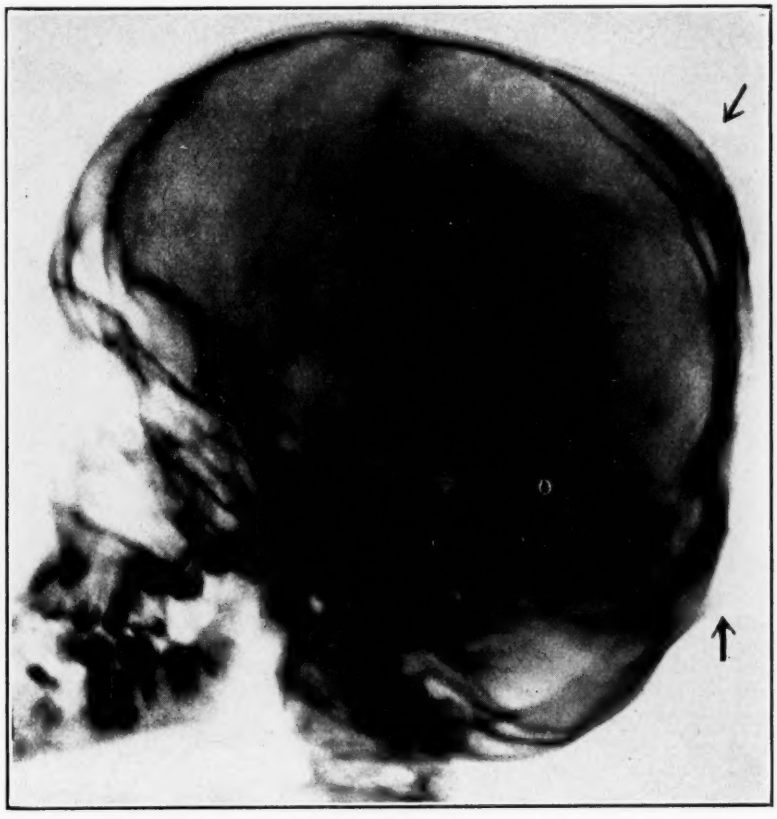

Fig. 2*B*.—Roentgenogram, Dec. 21, 1935, at the age of thirteen years. The osteomas of the calvarium show characteristic decrease in size and density.

The skull (Fig. 2) showed smoothly rounded osseous growths 1 to 2 cm. in diameter on the outer table of the calvarium in the left parietal and occipital regions; there were no visible changes on the inner table.

The spine (Fig. 3) showed a marked double-curved scoliosis, with small exostoses from the transverse processes of the fifth and sixth cervical vertebrae and wedging of the lumbar vertebral bodies.

Roentgenographic examination of the pelvis (Fig. 4) showed gross deformity of the pelvic bones. The outlet was narrowed and compressed to the left side. Irregular bony excrescences were present on the ilium above each acetabulum. The head and neck of each femur showed cortical thinning with progressively enlarging exostoses on the greater trocanters.

In examination of the knees (Fig. 5), the patellae were irregular, enlarged, and several bony masses were present anteriorly in the soft tissues below the right knee.

In the feet (Fig. 6), a mass of bone representing paraosteal ossification was present on the posteroinferior surfaces of the left calcaneous, and a smaller growth was present on the inferior aspect of the left cuboid. The cauliflower-like changes of the skin over this os calcis are shown in Fig. 7. A composite diagrammatic presentation of the skeletal changes is shown in Fig. 8.

Operations since his first admission to the University of Chicago Clinics include:

Sept. 4, 1929.—A large soft tumor 10 by 6 by 2 cm. was excised from the left flank, and this was found to be a flat oval lipoma. At the same time the tumor in the left epididymis was excised and proved to be a bluish cyst about 1 cm. in diameter. Microscopic examination revealed a hemorrhagic papillary cystoma.

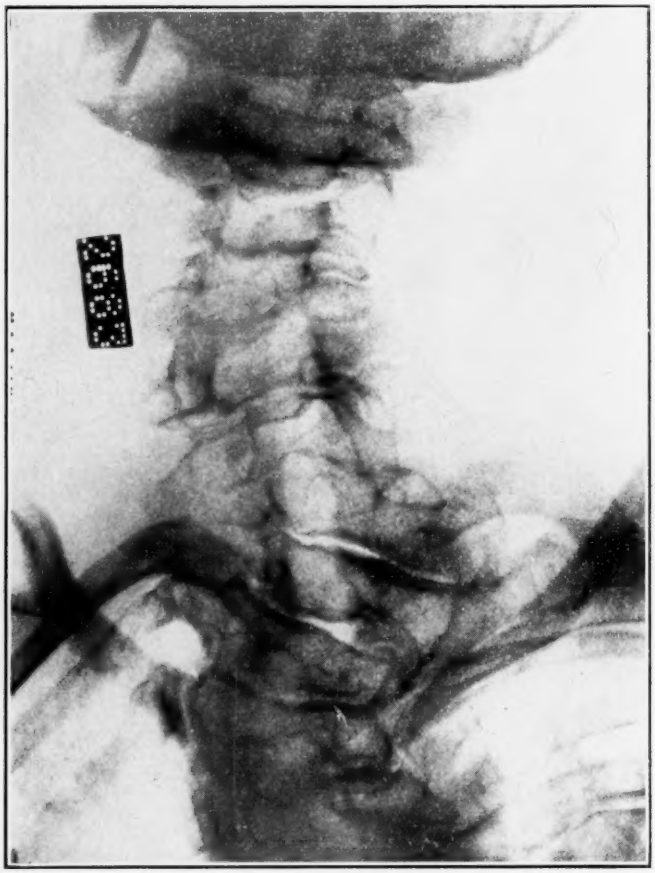

Fig. 3.—Roentgenogram, Dec. 21, 1935, aged thirteen years. Anteroposterior view of the cervical and upper thoracic spine. Bony growths may be noted on the transverse processes of the fifth and sixth cervical vertebrae.

Sept. 10, 1929.—A marble-sized mass of irregular bone was removed from the left cuboid on its plantar surface, and osteotomies were performed on the tibiae in an attempt to correct the genu valgum deformity. The mass of bone removed from the foot was studied microscopically and consisted of cancellous bone with some fibrous callous. There was no picture of true tumor bone. The section from the site of the osteotomy in the tibia revealed a thin cortex with thick fibrous periosteum. The cancellous bone was atrophic and the marrow spaces were filled with fat.

Oct. 9, 1929.—The small exostosis in the superior line of the left orbit was excised. This was covered with fibrous tissue and was spongy within. A pea-sized pigmented tumor was also removed from the left lower lip. The orbital mass proved to be a dense exostosis containing no cartilage. The soft tumor from the lip showed a mass of connective tissue in bundles of striated muscle containing some hair follicles. There was no evidence of neoplastic change or of neurofibroma.

Aug. 29, 1932.—A unilateral epiphyseal arrest was performed on the medial side of the distal femoral and proximal tibial epiphyses. Microscopic sections of the tissue removed showed normal bone and cartilage.

The patient was readmitted at intervals for observation and in January, 1933, he developed a right otitis media which has continued to discharge. The last hospital admission was in May, 1936. At this

Fig. 4.—Anteroposterior roentgenogram of lumbosacral spine and pelvis, Dec. 21, 1935, aged thirteen years. Large bony growths jut from the upper margins of both acetabula. The right caput and collis femoris are deformed and there is marked lipping of the lower margin of the right acetabulum.

time all of the deformities had increased so that walking was possible only with the aid of a cane. The skin and the subcutaneous tissue over the sole of the left foot have gradually hypertrophied until it presents the appearance of a coarsely corrugated, brownish mushroom-like growth. He has continued to attend school and to maintain his work with the average of his class.

DISCUSSION

Many reports of exostoses or of ecchondroses involving one or more bones of the body may be found in the literature, but general skeletal

Fig. 5A.

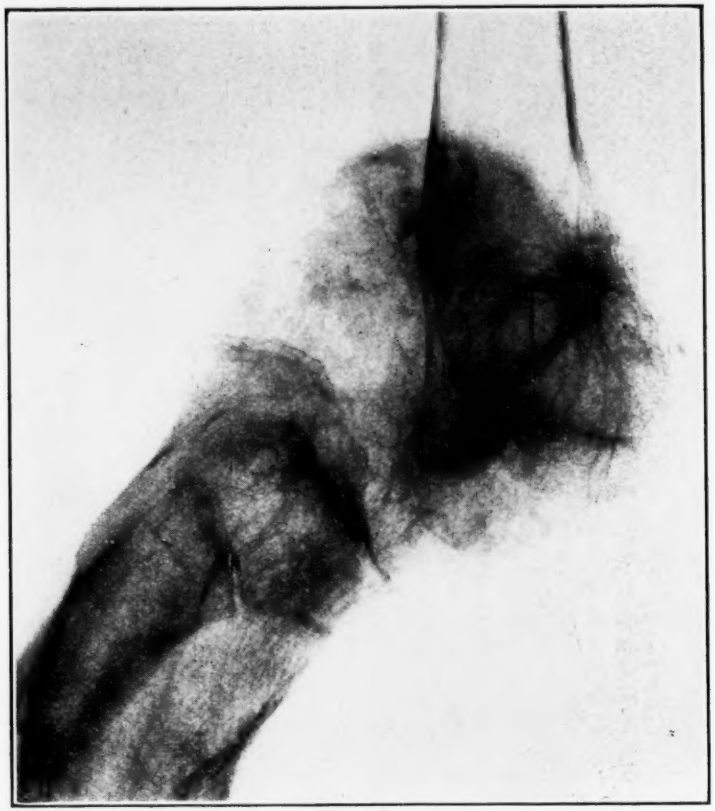

Fig. 5B.

Fig. 5A.—Lateral view of right knee, aged thirteen years. The overgrowth of the patella and its apparent union to the femur is seen. Two free osseous growths are present at the posterior aspect of the joint. The upper tibial epiphysis has hypertrophied and extends as a wedge-shaped bony process into the articular area.

Fig. 5B.—Lateral view of left knee, aged thirteen years. Note the new bone formation in the articular area and the subluxation of the tibia on the femur.

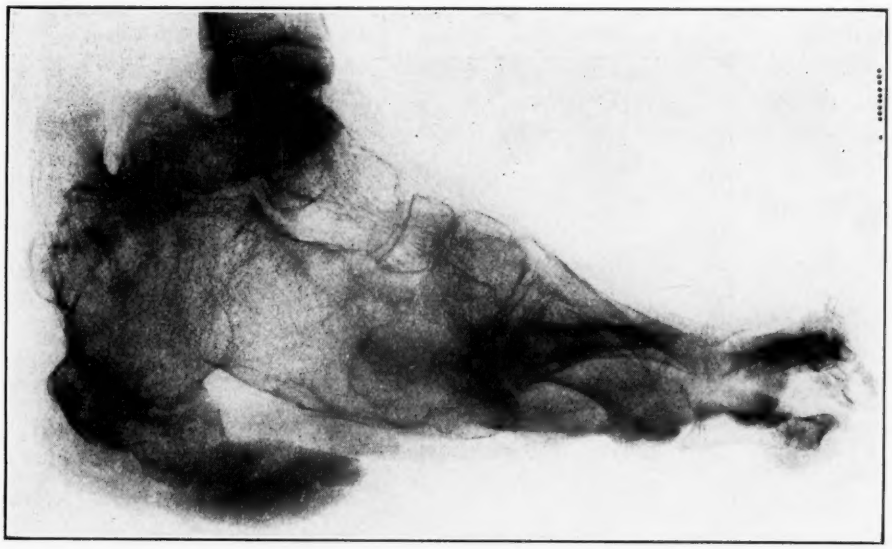

Fig. 6.—Lateral roentgenogram of the left foot, aged thirteen years. There is bizarre overgrowth of paraosteal bone about the calcaneus and cuboid bones with fusion at the lateral side of the transverse tarsal joint. A portion of the osseous mass has been removed from the cuboid. The free bony piece previously seen above the calcaneus has enlarged and united to both calcaneus and talus.

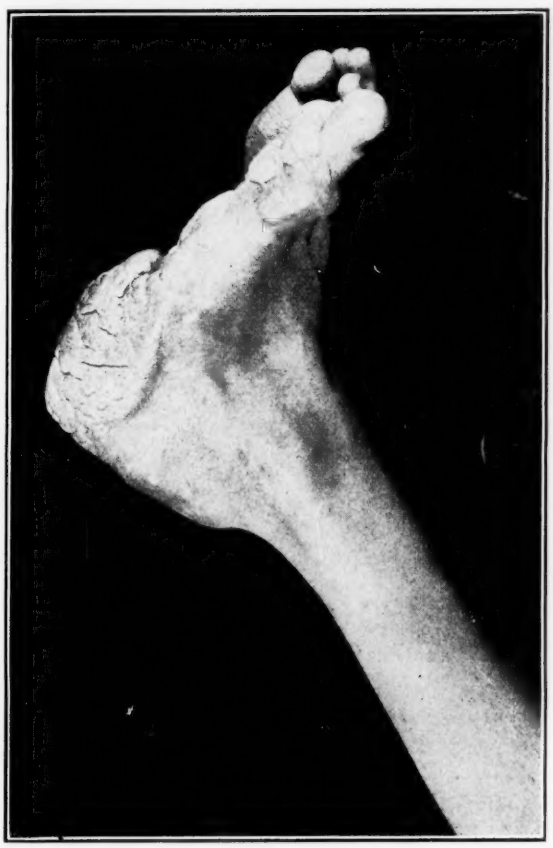

Fig. 7.—Dec. 21, 1935, aged thirteen years. The outer aspect of the left foot, showing the cauliflower hypertrophy of the skin; tumor growths from the calcaneus, and the fifth toe, and extreme deformity of the member.

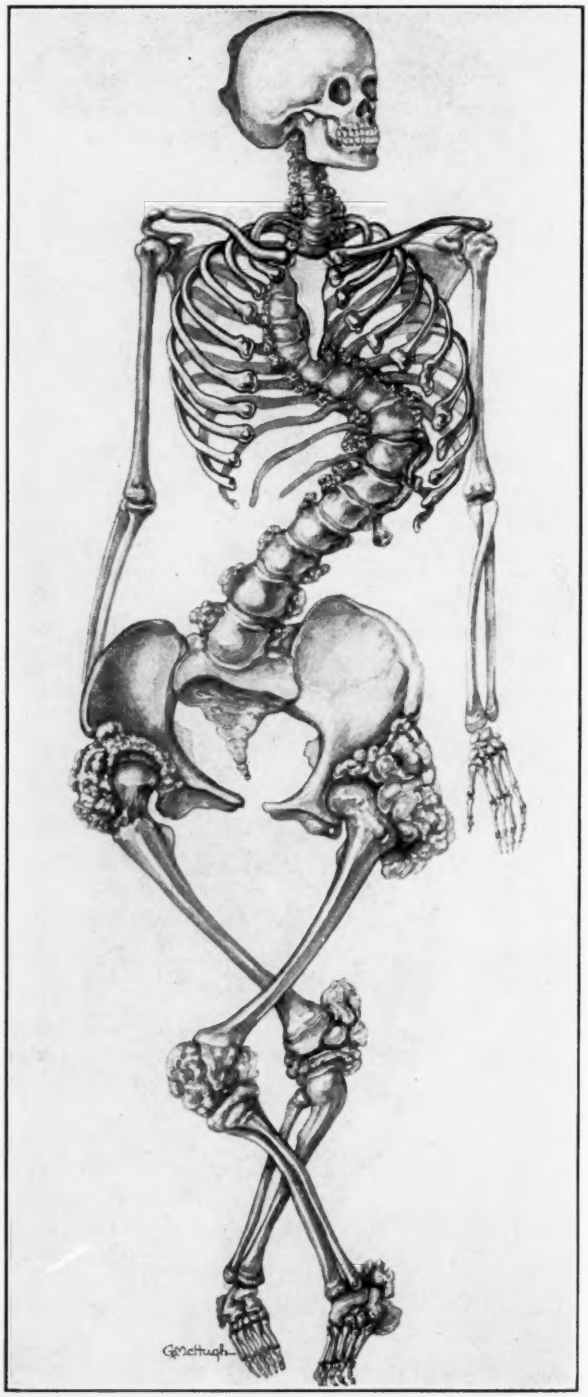

Fig. 8.—Diagrammatic composite drawing of the skeleton showing the extensive deformities and multiple masses of epiphyseal and paraosteal new bone.

deformity is rarely caused by or associated with these typically benign growths. Kaufmann[4] describes a case designated as exostosis cartilaginea multiplex, in which numerous chondral tumors existed at different sites on the skeleton. Particularly in this type of case may the pelvis be involved and deformed, producing an acanthopelvis or a pelvis spinosa. Multiple bony exostoses may occur in the region of the acetabulum and pelvic joints, and these often encroach upon the pelvic cavity. In our case however, the typical cartilage cap on the cartilaginous exostoses was lacking, and although some microscopic sections show cartilage-like cells such as may be found in callus, the growths are definitely osseous.

Edberg,[1] in a study of seven cases of multiple exostoses of the long bones, attributes the condition to regressive or aplastic changes in the thyroid. Von Haberer[2] noted that these multiple tumors frequently lead to growth disturbances of the bones because of encroachment on the epiphyseal lines. Kaufmann also describes the coincident occurrence of pigmented spots, telangiectatic formations, and lipomas. He believes that the multiple cartilaginous exostoses originate from cartilage islands displaced from the growth cartilages. In one of his cases, the subject showed over a thousand exostoses, but there was no general skeletal deformity. Exostoses of the calvarium tend to be static, exist at the time of or shortly after birth, and do not show comparable tendency to enlargement shown by similar tumors on the long bones.

In the case which we are reporting, progression of the deformities in spite of vitamin D medication would seem to eliminate rickets as an etiologic factor. Von Recklinghausen's disease of bone was excluded by finding normal mineral metabolism and by microscopic study of the bones themselves. Generalized neurofibromatosis with skeletal involvement was considered but microscopic sections of neither the bone nor the soft tumors showed the picture characteristic of this disease. Normal renal function excludes renal rickets. The etiology of the disease may be one of primary germ cell injury or defect and therefore a congenital developmental anomaly.

SUMMARY

1. A case of progressive osteodystrophy of unexplained etiology with marked skeletal deformities and multiple benign tumors of bones, skin, and subcutaneous tissue has been described.

2. The skeletal features of this case include the formation of massive, irregular exostoses of the calvarium, mandible, thorax, spine, pelvis, femora, tibiae, and left os calcis, associated with deformities of both lower extremities, marked scoliosis, and normal upper extremities.

3. Medical and surgical treatment failed to check the progress of the disease.

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SPINA BIFIDA OCCULTA

With Report of a Case in Which There Was an Occult Myelomeningocele

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SPINA bifida occulta is not an uncommon finding in routine roentgenograms of the spinal column. In a review of 12,000 such roentgenograms, Sutherland found evidence of spina bifida occulta in more than 5 per cent. In 70 per cent of the cases the first and second sacral vertebrae were the site of involvement; in another 25 per cent, the last lumbar vertebra was involved. In such roentgenograms one or more of the vertebral arches will be seen to be defective in that the two laminae have failed to fuse in the midline. This results in the formation of a defect or hiatus in the bony posterior wall of the vertebral canal. In most instances there is no accompanying visible aberration in the overlying cutaneous and fibromuscular tissues and the enclosed nervous elements function normally. Such cases are of interest, so far as the spina bifida occulta is concerned, only as slight anatomic variations. Steindler has questioned whether the condition should be considered pathologic unless it persists beyond the eighth year of life. Less commonly, however, there are seen cases in which the vertebral defect is complicated by evidence of nervous dysfunction and, usually, by gross evidence of malformation in the overlying tissues. These patients present interesting problems in diagnosis and treatment. They come to the attention of pediatricians, urologists, orthopedists, neurologists, and neurosurgeons.

ANATOMIC AND PATHOLOGIC CONSIDERATION

Spina bifida occulta has been well defined by Bucy as "a condition in which there is a defect in the posterior neural arches without any externally visible malformation of the spinal cord, its nerves or meninges." When such a malformation is visible externally, it is termed spina bifida cystica (or more commonly, simply spina bifida) and may be further subdivided into meningocele, meningomyelocele, and myelocele.

The origin of these related defects may best be understood by tracing briefly the normal development of the involved structures.[20] The neural tube, from which will evolve the spinal cord and its nerves,

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and the skin of the back are both derivatives of a single sheet of epiblastic (ectodermal) tissue. The neural tube has formed and is completely separated from the overlying skin by the end of the third week of fetal life. At the same time layers of mesoblastic (mesodermal) tissue have interposed themselves between the skin and neural tube and have joined in the midline. From these are derived the spinal meninges, the vertebral column, and the overlying muscles and fibrous tissue. The vertebral bodies have formed and their arches are closed by the end of the eleventh week of fetal life. At the time of their formation, the spinal cord and the vertebral column are of equal length and each segment of the spinal cord lies opposite the corresponding vertebral body. The paired spinal nerves pursue a direct course from the spinal cord to the intervertebral foramina. From the third month of fetal life on, however, the growth of the spinal cord fails to keep pace with that of the spinal column. As a result, the lower end of the spinal cord, the conus medullaris, comes to lie progressively higher and higher in the vertebral canal, until in the adult it reaches only to the lower border of the first lumbar vertebra. During this (apparent) ascent of the spinal cord, its nerves have necessarily become elongated and now pursue a diagonal course to the intervertebral foramina. This elongation is the most marked in the lumbosacral region and results in the formation of the aptly named cauda equina. The spinal cord retains a permanent connection with its original site of termination by means of the filum terminale, a thin fibrous strand extending from the tip of the conus medullaris to the posterior surface of the coccyx.

Spina bifida in any of its forms represents a perversion or arrest of this normal scheme of development of the spinal cord and its coverings. Specifically, it is a failure of the neural tube to close properly in the midline or to separate completely from the overlying skin. Furthermore, the mesodermal tissues either fail to fuse or are prevented from fusing in the midline. The etiologic factors underlying these perversions of development are apparently many and complex, and may vary in different cases.[22] Some authors have postulated that the primary defect lies in the neural tube itself (Fuchs). Recently, the importance of the mesodermal structures has been emphasized by Dittrich, who pointed out that the bony tissue is phylogenetically the youngest, and, therefore, presumably the least stable tissue present. Whatever the noxious influences may be, they must be active during the early weeks of fetal life.

The anatomic findings in cases of spina bifida occulta are extremely variable. By definition, the only constant feature is a defective formation or closure of one or more vertebral arches. One or more vertebrae may be involved, most commonly the last lumbar or first sacral.

The cervical vertebrae are less frequently involved and the thoracic vertebrae are only rarely involved. The vertebral laminae are absent, foreshortened, or malformed and do not meet in the midline. They may be of normal length but may lie in different planes and therefore may not meet.[14] There is no spinous process. It must be noted, however, that defects apparent in roentgenograms taken during childhood may be more apparent than real in that they may represent normally formed but, as yet, imperfectly calcified laminae.

In some cases, including most of those in which there are clinical symptoms, the presence of spina bifida occulta will be betrayed by the appearance of the overlying skin. There may be a small depression or dimple over the vertebral defect. In the lumbosacral region this is known as the fovea coccygea or fovea sacralis; it has been regarded as a certain indication (in the adult) of an underlying spina bifida occulta.[7] In some cases a thick patch of hair, an area of pigmentation, or an area of telangiectasis may overlie the defect. In still other cases, a fibrolipomatous mass will occupy the subcutaneous tissues and cause a gentle elevation of the surface of the skin.

The hiatus in the defective vertebral arch may be patent or it may be closed by a tough membrane, which von Recklinghausen named the "membrana reuniens posterior." This may, in some instances, become much thicker than the bone which it replaces and may then protrude into the vertebral canal, narrow its diameter, and at times compress the spinal cord. The membrane frequently is attached to the overlying skin by a tough band of connective tissue. It may, likewise, be attached to the underlying dura. At other times there may be a cleft in the membrane through which passes a fibrous strand that connects the skin and dura. This strand may, at times, be canalized and form a so-called congenital dermal sinus which is comparable to a pilonidal cyst (Walker and Bucy). Any of these unnatural attachments to the dura may angulate it, produce deformity of the dural sac and at times cause compression of the enclosed cord and nerves.

The defects in the nervous tissues are of greatest importance but little is known about them. Frazier and Dittrich expressed the opinion that in cases of spina bifida occulta the spinal cord and its nerves are usually normally developed and that any degeneration in them is secondary to pressure from deformed meninges and vertebrae. Mixter observed that the nerve tissue, as seen at operation, is usually deformed; the most common malformation is a fusion of the cauda equina into a single irregular bundle which has the appearance of a small spinal cord. Fuchs maintained that the spinal cord is always deformed in cases of spina bifida occulta and applied the term "myelodysplasia" to this condition. He reported several cases in which the failure of dorsal fusion was limited to the spinal cord; the verte-

brae were normal. Woltman also has reported three such cases. Much of the confusion evidenced by these discordant opinions may be attributed to differences in the definition of terms and to a surprising paucity of careful anatomic studies of cases of spina bifida occulta. In the absence of such knowledge, positive statements are not warranted. It is certain, however, that what may grossly appear to be a normal spinal cord will be found, upon careful examination, to be hydromyelic; that is, to have an abnormally large central canal, presumably the result of faulty closure of the neural tube. Such a defect need not impair the function of the cord unless it be present in marked degree. At times the spinal cord is found to terminate at an abnormally low level.

Some of the defects which may be present in the spinal dura have already been mentioned. The dura may be enlarged generally or locally. In the latter case the outpouching of dura will constitute a meningocele; or if it contains nerve elements, a myelomeningocele, which in this case will be occult since, by definition, it cannot make its presence known by visible protrusion. Such an occult meningocele or myelomeningocele will usually pass through the hiatus into the subcutaneous tissue, but not to the surface of the skin. We have encountered a case (to be related in detail later in this paper) in which a hitherto unreported anomaly was discovered; namely, an occult myelomeningocele in which the dural cyst, instead of passing out through the hiatus, remained within the confines of the vertebral canal, where it acted as an extradural tumor of the spinal cord and compressed the fibers of the cauda equina.

The frequent association of benign neoplasms and spina bifida occulta has been noted. Lipomatous masses very commonly are found either in the subcutaneous tissues or in the vertebral canal, where they may lie extradurally or intradurally, intimately attached to the fibers of the cauda equina. They may be of "dumbbell" or "hourglass" shape, with the narrow portion occupying the hiatus in the vertebral arch. Dermoids, when present, usually lie extradurally. Exostoses have been found encroaching on the vertebral canal in the region of a spina bifida occulta.[2] All of these may act as tumors of the spinal cord.

Developmental anomalies elsewhere in the body are frequently noted in conjunction with spina bifida occulta. These may be divided into those which are coincidental, as hydrocephalus, absent vertebrae, cleft palate, congenital dislocation of the hips, syndactylism, cryptorchidism and ectopia of the bladder; and those which may be presumed to be secondary to the neurologic defect inherent in the spina bifida occulta, as pronated feet, talipes equinus, and hammer toes.

SYMPTOMS

The symptoms of spina bifida occulta, when any are present, are the result of neural dysfunction. Unless present from birth or infancy, they commonly make their appearance at the time of puberty or during early adult life. This circumstance is related to the fact that there occurs at this time a period of rapid body growth, as a result of which mechanical stresses are applied to the nervous tissues. The malformed spinal cord and meninges may be prevented by unnatural attachments from undergoing the changes incident to the lengthening of the cauda equina. Abnormal structures, such as the membrana reuniens and benign tumors, may enlarge to a point where they begin to compress the nervous elements. It has likewise been proposed that the myelodysplasic spinal cord may be less able to withstand normal stresses than the normal spinal cord.

The symptoms produced by spina bifida occulta will, of course, vary with the segment of the spinal column involved. Practically, however, lumbosacral spina bifida occulta is most worthy of consideration since it occurs so much more frequently than any other form. The most common symptoms of lumbosacral spina bifida occulta are related to the urinary tract; persistent enuresis is an outstanding symptom. Among twenty-two adults who had nocturnal enuresis, Peritz found that 68 per cent had lumbosacral spina bifida occulta; among a like number of children, the incidence of spina bifida occulta was 35 per cent. More serious interference with the neuromuscular function of the urinary tract may produce urinary retention, with or without overflow incontinence, and may lead at times to hydro-ureter and hydronephrosis. Mertz attributed the "idiopathic congenitally dilated ureter" to spina bifida occulta. Impotence may occur among men. Rectal dysfunction is much less frequent than vesical dysfunction.

Motor and sensory disturbances may occur in any segment of the spinal column. Lumbosacral lesions may produce the syndrome of tumors of the conus medullaris or cauda equina. The paralysis in the extremities may be flaccid or spastic; foot-drop is a common symptom. If the paralysis is present for a considerable time, muscular atrophy will supervene. So-called virginal prolapse of the uterus, appearing in infancy or among nulliparous women, has been attributed to weakening of the muscles of the pelvic floor secondary to spina bifida occulta.[8] Interference with the motor and vasomotor nerves to the lower extremities by spina bifida occulta has been considered a frequent cause of hollow and clawed feet and hammer toes, particularly when these deformities make their appearance or become progressively worse after birth.[1, 11]

The most frequent type of sensory disturbance associated with lumbosacral spina bifida occulta is one limited to the sacral and lower

lumbar segments, a so-called saddle anesthesia. Other distributions may, of course, occur. Thermal anesthesia, which is said to be more marked than other qualities of sensation, may lead to serious burns. Pain of sciatic distribution rarely is a symptom.

Another group of symptoms closely related to the motor and sensory paralyses are the so-called trophic disturbances. These are common about the feet in cases of lumbosacral spina bifida occulta; they have been observed in the hands in cases of cervical spina bifida occulta. Ulcers are prone to form and reluctant to heal. An indolent ulcer should always make one suspicious of spina bifida occulta. The skin may be thin and glazed, and terminal atrophy and gangrene of the digits have been seen.

The weakening of the skeletal structure of the back as a result of spina bifida occulta has been considered a cause of low back pain and habitual scoliosis. The etiologic relationship here is speculative.

DIAGNOSIS

The diagnosis of spina bifida occulta is easily made if the condition is suspected. Physical examination may suggest the diagnosis even when the condition is not suspected. One of the lesions of the skin may direct attention to the spinal column. The examining finger may detect the absence of one or more vertebral spines and pressure over this defect may cause pain which will extend to the extremities.[4] Roentgenograms of the spinal column furnish objective evidence of the vertebral defect and its extent. In the presence of such a defect and in cases in which the characteristic symptoms are present, careful neurologic examination should be made and the functional state of the vesical sphincters should be determined. Other possible causes of the symptoms must, of course, be eliminated before attributing them to spina bifida occulta.

The most important step in the diagnosis is an estimation of the relative rôles played by myelodysplasia and by mechanical compression of nerves in the production of the symptoms. Such an estimate is essential, for on it depends to a large degree the adoption or rejection of surgical treatment. Careful consideration of the history, with particular reference to the chronology and progression of the symptoms, and careful consideration of the present neurologic status of the patient are necessary. Defects and dysfunctions which were present at birth and have not been progressive are likely to be the result of malformation or permanent injury of the spinal cord and nerves. When the symptoms make their appearance during life, particularly if they are progressive, mechanical interference with nerve function is suggested. Both congenital and mechanical lesions may, of course,

be present together in any case. The introduction of radiopaque oil (lipiodol) into the subarachnoid space, with subsequent roentgenoscopic and roentgenographic observation of its movement and distribution, occasionally has been found valuable in visualizing the condition of the nerves and the presence of subarachnoid block.[14, 17] However, this procedure is not entirely without risk and should rarely be necessary. Lumbar punctures should be performed with great care in the region of a spina bifida occulta, as there is danger of injuring abnormal nerve tissue.[1]

We have observed a case which illustrates well a number of points in connection with the diagnosis and treatment of spina bifida occulta and which demonstrated the beneficial results of neurosurgical intervention in suitable cases. There also was a unique pathologic finding.

REPORT OF CASE

A man, aged thirty-eight years, registered at the Mayo Clinic on Aug. 15, 1935, complaining of deformity and chronic infection of his left foot which had been present for ten years. He was the father of a normal child. Ten years before he came to the clinic a "hammer toe" deformity of the second toe of the left foot had developed; this had been corrected surgically. Shortly thereafter, the patient had run a nail into the sole of his left foot near the head of the second metatarsal bone. An ulcer had developed at this point and had drained intermittently. Flexion deformities of several other toes also had developed later and the patient had noted the appearance and gradual spread of anesthesia over his left foot. In recent months, before he came to the clinic, he had been forced to use crutches in order to get about, because painful and infected callosities had developed on the sole and heel of the left foot.

Examination revealed a small dimple in the skin over the lumbosacral junction. There was a hammer-toe deformity of the second toe of the right foot. The second toe of the left foot had been surgically removed. The skin of the left foot was smooth and thin; on the plantar surface, between the heads of the second and third metatarsal bones, was a draining sinus. The lateral aspect of the heel was covered with a chronically infected callosity. Neurologic examination revealed that the muscles of the right leg and right foot were moderately weak and slightly atrophied. The hamstring reflex and Achilles reflex were absent on the left side. There was a definite hyperesthesia to all forms of sensation over the left foot and lateral aspect of the left leg. Laboratory examination of the blood and urine did not reveal anything abnormal. A flocculation test for syphilis was negative. Roentgenograms of the left foot showed no active infection in the metatarsal bones. The roentgenogram of the lumbosacral region revealed a spina bifida occulta of the first sacral segment with deformity of the arch of the last lumbar vertebra. A diagnosis of spina bifida occulta with myelodysplasia was made and exploration was advised.

On Aug. 23, 1935, one of us (J. G. L.) performed laminectomy through a midline skin incision with the sacral dimple as its midpoint. When the deformed laminae of the last lumbar and first sacral vertebrae were removed, there was exposed a bulging tumor which had the appearance of the dural sac and which pulsated as does the normal spinal dura (Fig. 1*a*). The laminae of the fourth lumbar vertebra were removed; they were found to be thinner than normal. The tumor could

then be seen to arise from the dorsal surface of the normal dura at a point opposite the laminae of the fourth lumbar vertebra and to extend caudally to the level of the defect in the arch of the first sacral vertebra, but to remain confined entirely within the limits of the vertebral canal. The tumor was cystic. When opened it was found to contain cerebrospinal fluid and to communicate with the spinal subarachnoid space by means of a small ostium through which projected a mass of tissue which appeared to be continuous with the spinal cord; that is, to represent an aberrant mass of nerve tissue (Fig. 1*b*), possibly an elongated conus medullaris. This was dissected free from the sac and replaced within the spinal subarachnoid space. The myelomeningocele sac was then severed from the dura (Fig. 1*c*) and a plastic closure of dura and subcutaneous tissues was made. The lumbosacral fascia was sewed together in the midline.

Postoperative convalescence was uneventful. Within two weeks after the operation, the patient said that the foot felt better. Neurologic examination did not show any change from the preoperative condition except that the ulcer on the sole of the left foot had healed. The patient was permitted to return to his home at the end

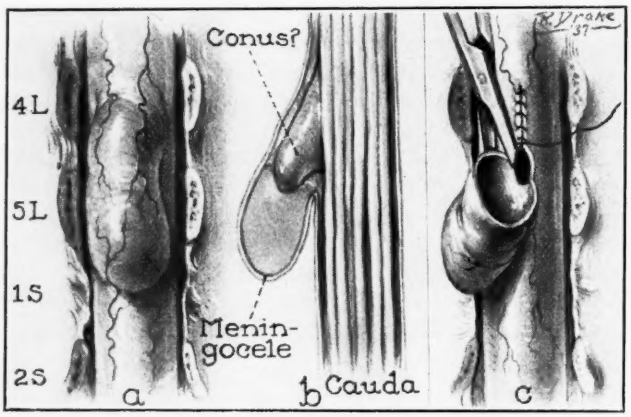

Fig. 1.—*a*, Failure of development of the laminae of the first sacral vertebra and thinning of the laminae of the fourth and fifth lumbar vertebrae from pressure of the occult myelomeningocele; *b*, diagrammatic lateral view of the tumor and cauda equina; *c*, resection of the meningocele and plastic closure of the dura mater.

of the third week. He has since reported that the ulcer has remained healed and that the callosities of his heel are less troublesome. He is able to get about without aid and with comfort.

NEUROSURGICAL TREATMENT

The neurosurgical treatment of spina bifida occulta is directed toward improving nerve function by relieving mechanical interference. Obviously, nothing can be done to improve the function of malformed or degenerated nerve tissue. We already have considered the diagnostic aspects of this problem.

It is impossible to set forth hard-and-fast rules to govern the adoption or rejection of operative treatment. So many factors enter into each case that one can only indicate general principles. It is generally agreed that only severe and progressive symptoms call for exploration.

On the other hand, severe paralysis of the lower extremities, which has been present since birth, is regarded as a contraindication to operation.

Brickner suggested that operation be undertaken in all infants and children in whom spina bifida occulta was associated with subcutaneous lipomas or areas of hypertrichosis, whether symptoms were present or not, the aim being to forestall future trouble. Most authors regard this as too radical an attitude. It is also agreed that enuresis of childhood, without other symptoms, is not an indication for operation, and even when it occurs among adults Bucy warns against laminectomy when the condition is mild, because even slight operative trauma to the nerves may make the condition worse than it already was. This injunction may well be borne in mind in all cases of this type.

Operation should be considered, however, in all cases of severe urinary dysfunction, especially if the symptoms appear or become worse at the time of puberty (Mixter). Mertz reviewed seventy-nine reported cases in which laminectomy was performed for spina bifida occulta which was associated with disturbance of the nervous control of the lower part of the urinary tract. In half of these cases the patients were relieved and in the other half of the cases the patients were helped, although relapses were common. He noted, as have others, that operation may benefit certain of the patients' symptoms and not others. Patients who have trophic lesions, such as perforating ulcers, are often favorable subjects for operation.[12]

It is likewise agreed that operation for relief of deformities of the pedal extremity, such as talipes equinus, should be undertaken only in the face of a progressive lesion. Hackenbroch operated in seventy such cases; beneficial results were obtained in half of the cases in which definite abnormalities were found in the epidural space.

Since it is impossible to predict with certainty what will be found at the time of operation, disappointing results will often follow laminectomy in cases of spina bifida occulta. However, in consideration of the very low operative mortality and the very definite benefits which frequently accrue, operation should be seriously considered in every case.

The operative procedure employed will vary in each case. In any event, a laminectomy is performed in the region of the defect, and sufficient bone is removed to permit a thorough inspection of the dural sac. In most instances it will be wise to open the dura for inspection of the cauda equina, if only to be able to estimate the prognosis for improvement following the surgical procedure. The measures necessary to relieve mechanical stress on the nervous tissues will, of course, vary with the exact condition found at exploration, and must be decided on at the time of operation. Great care must be exercised not to injure already incompetent nerves.

SUMMARY

Spina bifida occulta is a developmental defect of the spinal cord, its meninges, the vertebral column, and the overlying muscular and cutaneous tissues. It begins in early embryonic life. A review of the literature emphasizes the wide variety of anatomic malformations which may occur. These may be divided into those which affect the nervous tissues themselves (myelodysplasia) and those which occur in the mesodermal tissues surrounding and supporting the spinal cord, including its meninges. In most instances these defects will not be great enough to compromise the function of the spinal cord and its nerves. The condition will remain subclinical but may be recognized in roentgenograms of the spinal column.

When clinical symptoms accompany spina bifida occulta, they usually are the result of neural dysfunction. This may result from defects inherent in the nervous tissue (myelodysplasia) or from mechanical interference with the function of nervous tissue by the tension or pressure of adjacent tissues. The most common symptoms are those which are related to the urinary apparatus. Motor, sensory, and trophic disorders about the lower extremities are likewise common and should always arouse the suspicion of spina bifida occulta. Pain is rarely a symptom. Certain malformations of the feet and toes (talipes equinus, hammer toes) have been attributed to spina bifida occulta in many cases. Once spina bifida occulta is suspected, it is easily verified.

Surgical treatment, in the form of exploratory laminectomy and attempted relief of mechanical interference with nerve function, should be considered in every case in which the symptoms appear or become progressively worse during postnatal life. Although only partial relief of symptoms may be expected in most cases, the low mortality of the surgical procedure justifies its trial in most instances.

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RESECTION OF THE ELBOW JOINT

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REVIEW OF LITERATURE

ALTHOUGH Hippocrates and Celsus both alluded to the removal of the articulating extremities of dislocated bones, the first application of resection to the elbow joint is attributed to Wainmann[1] in 1758. Macartney[2] noted that the procedure was practiced in the last decades of the eighteenth century by Filkin (1786), Moreau (1794), and Park (1794). Cases, successfully resected, were reported by Nickels[3] in 1837 and two years later by Bier.[4] The procedure gained its place in British surgery only after the enthusiastic recommendation of Syme,[5] and was first performed in America independently by Buck[6] and Pancoast[7] in 1842.

A variety of techniques have been described by Langenbeck, Kocher, Park, Moreau, Heuter, Chaissaignac, Dupuytren, Faraheuf, and Nélaton.[8] Its greatest proponent was Ollier,[9] who wrote profusely on his method, and who performed a total of 270 resections from 1859 to 1900. In the Musée Ollier are 120 elbow joint specimens, 86 of these resected for tuberculosis.

The early literature abounds with numerous articles and monographs on the resection of joints, but in recent years this has been greatly supplanted by the interest of surgeons in arthroplasty. Between the years 1837 and 1883, 235 authors contributed numerous reports, and 39 monographs were printed, on resection of the elbow joint, with noteworthy contributions by Hodges[10] in 1861 of 119 cases and by Culbertson[11] in 1876 in his prize essay including 1,082 elbow joint resections collected from the world literature, and from 1883 to 1900 over 180 authors added many more articles and monographs. Between 1900 and 1925, 75 articles and 6 monographs were published, and since then only 13 authors have contributed on this subject.

Comte[12] in 1925 studied 55 of Ollier's resections for tuberculous arthritis of the elbow joint, followed from five to sixty years, with 94 per cent satisfactory results, and 100 per cent excellent results in 21 resections for nonspecific arthritis and malunited, disabling fractures. Sorrel, in commenting on Gruca's[13] four cases (1932), stated that he had performed 50 resections with a high percentage of success. Nové-Josserand and Pouzet[14] (1932) have utilized resection and hemiresection in the treatment of chronic, irreducible dislocations of the elbow

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joint. Rebaudi[15] (1934) reported 14 cases, and Buzby[16] (1936) recorded 13 elbows successfully resected out of 15 in a series of 14 cases, 3 of these for tuberculous arthritis. Most recently, Magnusson[17] (1936) has reported the combined resection and interposition of fascia lata in 17 cases of tuberculosis of the elbow, with satisfactory motion in 16 and with ankylosis in 1.

INDICATIONS

There has been some controversy as to the relative merits of resection of the elbow joint and arthroplastic reconstruction.

We take issue, on the basis of the experience of many others as well as our own, with the statement of MacAusland[18] (1922) that: "The results from this (excision) are very unsatisfactory, the joint being flail, weak and usually requiring external treatment in the form of a leather with limited elbow joint motion. . . . The ultimate results from its use do not warrant its being considered for any condition except tuberculosis of the elbow"; and with that of Campbell[19] (1929): "An arthroplasty is often the only procedure that offers hope for the reestablishment of motion and of function in an elbow severely injured by fractures about the elbow joint." Certainly a more conservative note is struck by Jones and Lovett:[20] "It is an open question whether this operation (arthroplasty) has sufficient advantage over excision to warrant one in pronouncing it the operation of election."

Arthroplasty, introduced as a refinement of excision, has for its chief object not only the interposition of a layer of fascia or membrane, but the reconstruction of the bone ends, in such a way as to adopt the opposing surfaces and so give stability as well as movement to the new joint. In an attempt to avoid the slight instability that often follows a resection and the occasional flail elbow, French surgeons resorted to a less free removal of bony tissue and attempted to avoid reankylosis by interposing muscle tissue. Many interposing media have been utilized—inorganic substances, fat, pedicled fascia fat (Murphy),[21] animal membrane (Baer),[22] heterogenous fascia, and autogenous fascial transplants (Putti,[23] Hey-Groves,[24] MacAusland,[25] Campbell,[26] Albee,[27] and others).

However, a moderate degree of lateral instability in a resected elbow does not represent a disability as the elbow is a nonweight-bearing joint, while a flail elbow is an infrequent occurrence, following only very extensive resections. Large series of resected cases have demonstrated the restoration of very satisfactory function. The attempt in arthroplasty to restore the anatomic conformation of the joint and to prevent instability by a minimum amount of bony sacrifice and the interposition of fascia harbors the greater possibility of reankylosis, as has been shown experimentally by Allison and Brooks and as has been proved clinically in many instances.

Tuberculosis of the elbow joint occurred in 2 per cent of 224 joints operated upon in Cleveland's[29] series (1935). Resection of this joint is considered by most authorities[20, 30, 31] the operation of election for adult tuberculous arthritis, in the presence of progression despite conservative treatment. Fusion, unlike its application to other joint tuberculosis, has not been so acceptable to the elbow joint, not only because of technical difficulties and the awkwardness of an ankylosed elbow, even in good functional position, but also because it fails to extirpate the disease process and there is a frequency of recurrence and progression. Cleveland[29] writes: "I now believe a careful resection may be a better and more logical procedure in this nonweight-bearing joint. Our record of only one successful fusion in five attempts leaves much to be desired." According to Comte,[12] 55 of Ollier's cases resected for tuberculosis, showed 95 per cent satisfactory results from five to sixty years postoperatively, while Oschman,[30] of Kocher's clinic, reported 70 per cent excellent results in 40 cases (1872 to 1897). Steindler[31] cites Garre's statistics of 51 per cent cures in 235 cases, Konig's of 54 per cent cures, and Bardenheurer and Lossen's of 63 per cent cures and 70 per cent good functional results. Fatal miliary tuberculosis may ensue, as it may follow the interference of any tuberculous focus, Konig[32] observing 16 cases, and Wartman[32] 26 cases out of 225 deaths in 837 collected cases of elbow joint resection.

Resection is indicated in ankyloses of all origin, fibrous or osseous, traumatic or infectious in origin. Following pyogenic infections, no interference is advised until several years of quiescence have elapsed and only after a vigorous manipulation fails to activate any latent process. In ankylosis due to rheumatoid arthritis, despite a long quiescent interval with normal clinical and laboratory findings, operative interference may be followed by a reactivation of systemic and local manifestations.

Resection is of value in the rehabilitation of elbow joint fractures with deformity and disability, and in chronic irreducible dislocations. During the World War, considerable was written on the merits of its use following débridement for gunshot wounds and compound fractures of the elbow region. The satisfactory results that not infrequently follow a conservative regime in comminuted simple and compound fractures of the elbow do not warrant such immediate radical therapy in civil surgery.

This operation is valuable in the extirpation of benign and locally malignant osseous tumors.

Although Annandale, Ashhurst, Chassaignac, and others advocated its use in the first decade of life, the experience of most surgeons is that resection is best delayed until the cessation of the growth period, not only to avoid an unsightly shortened extremity, but also to avoid

reankylosis. The osteoplastic activity of the elbow region in young patients is a distressing feature known to all those interested in traumatotherapy. Besides, in young children one cannot resect so freely, as they do not possess a sufficiently well-developed musculature to assure satisfactory stability in a freely resected joint. Finally, the postoperative cooperation, which is so essential to obtain a good result and which is often painful and trying, is found wanting in a child.

MODUS OPERANDI

A variety of incisions have been advocated, many so placed as to disregard and indiscriminantly sever the ulnar nerve.[8]

Ollier's method of "resection sous capsulo-périostée," for which he gave credit to Verneuil, aimed at the removal of the bones alone, leaving the periosteum to admit a reformation of all the structures of the joint. Other surgeons have recommended the free sacrifice of all adjacent periosteum and soft tissues in the so-called open method. Ollier's excellent results in great part depended on what he considered as the sine qua non of a successful elbow resection, i.e., a liberal excision of bone and the early mobilization of the new joint.

The operation is performed without the use of a tourniquet. It is wise, in an elbow that has not functioned for a long time, to reactivate the muscles preparatory to resection with massage and electrical stimulation.

1. A posterior longitudinal incision is made, extending 3 inches above and 3 inches below the olecranon process.

2. The medial skin flap is retracted and the ulnar nerve is isolated between the medial condyle and olecranon process, freed upwards and downwards, and retracted gently.

3. The triceps tendon insertion and a small portion of the attached olecranon process, severed with an osteotome, are retracted upwards, exposing the posterior portion of the elbow joint. This procedure, employed since 1931, has obviated the residual triceps weakness that followed our previous technique. Several German surgeons, Trendelenburg, Mosetig-Moorhoff, and Spuhn, and Senn, of America, have recommended the preservation of the olecranon process with its attached triceps tendon, reuniting it with metallic pins.

4. The periosteum is elevated laterally and medially from the lower end of the humerus and the upper ends of the radius and ulna, with the attached flexor and extensor muscle groups. This is continued anteriorly until the joint has been completely exposed and the vital structures of the anticubital fossa displaced anteriorly and well protected.

5. The humerus is sawed completely through above the condyles, about 1 inch above the joint surface.

6. The inferior site of resection is now easily exposed by forcing the partially excised elbow posteriorly and well into the wound. If the superior radioulnar joint is intact, it should be preserved and the ulna alone resected just above the radial head. If, however, this joint is involved, the radial head and ulnar upper extremity are excised at a level just above the radial tuberosity. The bared ends are smoothed and rounded off with rongeurs and a bone file. No bone wax is utilized. A total of at least 1½ to 2 inches must be removed from the humerus, radius, and ulna. It is our experience that the common fallacy is the removal of too little rather than too much bone.

7. A firm stitch of No. 3 chromic catgut is passed through the triceps insertion, and a drill hole, made at the upper end of the ulna, and sutured to the surrounding periosteum, the small olecranon fragment contacting the fresh bony surface of the upper ulna.

8. The deep tissues—periosteum, capsule, muscle, and fascia, are all sutured as one with No. 1 chromic catgut, the subcutaneous tissues with plain catgut, and the skin with dermal or silk sutures. A small rubber drain is inserted at the lower angle of the wound for twenty-four to forty-eight hours.

9. A plaster splint is applied posteriorly with the elbow flexed at a right angle and the entire extremity is suspended to reduce postoperative swelling.

10. Active and passive exercises are instituted as soon as the acute reaction in the operative site has subsided, i.e., as early as the third or fourth postoperative day.

Skin sutures are removed on the tenth day postoperatively and an intensive course of baking, massage, and sinusoidal stimulation to the flexor and extensor muscles of the elbow joint commenced. A sling is worn for three months to prevent abnormal traction on the soft tissues of the elbow region and undue lateral motion. We have found a brace or other external support unnecessary in our cases.

Good active flexion is obtained in two to three months, but complete recovery must not be anticipated in less than six months, until the lax elbow soft structures have adapted themselves to the resection, and concomitantly, lateral instability grows less marked. A residual 10° to 15° of lateral motion which usually persists is consistent with a satisfactory functional result.

The operation of brachial hemiresection, as practiced in the clinic of Nové-Josserand for chronic, irreducible posterior dislocations of the elbow joint, consists of the removal of a liberal portion (1½ inches to 2 inches) of the lower end of the humerus with preservation of the forearm bones. In the antibrachial type of hemiresection, only the upper extremities of the radius and ulna are extirpated.

REVIEW OF AUTHORS' CASES

The seventeen cases herein presented were operated upon by the senior author (A. J. D.), the first in 1914. Their ages vary from five to forty-six years—3 in the first decade of life, 5 in the second, 2 in the third, 5 in the fourth, and 2 in the fifth. Seven cases were operated upon prior to the cessation of the growth period. There are 2 females and 15 males in the series.

Two of the elbows were the site of proved tuberculosis, one aged five years, the other thirty-six years, with painful and restricted motion. In 13 cases there was complete loss of motion of the elbow joint, with fixation at angles varying from 90° to 165°, due to comminuted fractures or fracture-dislocations in this region. There were 2 cases of old, irreducible dislocations of the elbow joint.

In 1 case there was a complicating musculospiral nerve paralysis due to involvement of the nerve in callus, and this required liberation of the nerve concomitantly with the resection.

Resection was performed four months to one and one-half years following the onset of disability in 15 cases, and in one case eighteen years and in another thirty-four years following the original injury.

Total resection was performed in 14 cases, the brachial type of hemiresection in 2 cases of old, comminuted fractures of the lower end of the humerus, and the antibrachial type in 1 case of chronic, irreducible fracture-dislocation.

The duration of follow-up study since the performance of the resection in the collected cases varies from six months in 1 case to ten years in 2, with 9 patients observed from one to five years, and 5 from six to nine years.

In 11 of the 17 cases, 9 adults and 2 children aged nine and thirteen years, the results were excellent, with restoration of complete active and passive motion and with lateral motion of only 10° to 15°. The function in all of these cases is very satisfactory and several have returned to hard manual labor. Five of the cases show some residual extensor weakness against gravity and resistance, while the remaining 6, operated upon since 1931, evidence excellent restoration of this power due to the preservation of the triceps mechanism. In 1 case, some restriction of flexion due to an anterior bony block at the lower end of the resected humerus disappeared in one year following persistent physiotherapy and very gentle manipulation.

In our most recent case, an extensive resection was performed six months ago for tuberculous arthritis with pain and restricted motion, and at present there is a complete restoration of passive motion, with active flexion and extension against moderate resistance. Considerable instability of 25° to 30° is still present, but this is gradually lessening. The disease process has been extirpated and the prognosis is good.

In 2 children, aged seven and eleven years, only partial but satisfactory motion has been restored, in the former ranging between 70° and 110°, and in the latter, from complete flexion to 120°. In the former a complicating musculospiral nerve involvement was successfully corrected by neurolysis at the time of resection. A brachial hemiresection had been performed in the other patient for an unreduced fracture-dislocation.

Reankylosis occurred in 3 cases, aged five, eleven, and fifteen years. The first case had tuberculosis of the elbow joint, and developed postoperatively a secondarily infected sinus with a resultant ankylosis at 80°. The other 2 cases had sustained comminuted fractures about the elbow joint. One had a brachial type of hemiresection with reankylosis at 125°. The other, a female, had a total resection but cooperated very poorly in her postoperative regime with resultant ankylosis at 90°.

Postoperative roentgenograms of the successfully resected elbows showed a rounding off and sclerosis of the articulating bony margins, with their approximation until only a narrow joint space intervened. Occasionally bony particles and fragments were noted in the surrounding soft tissues, but these did not vitiate the good function of the nearthrosis. The olecranon fragment, where it had been preserved, became reattached by osseous union. In the 2 children with partial restoration of function and in the 3 with reankylosis, considerable postoperative osteoplastic formation was evident.

In summary, the results of elbow joint resection have been very satisfactory in all of our adult patients (9), but in only 2 children. Of the remaining 5 children, a partial but satisfactory restoration of function has occurred in 2 and ankylosis in 3, 2 of the latter in a good functional position. Brachial hemiresection resulted in a complete ankylosis in 1 child and in a partial ankylosis in another. The antibrachial type of hemiresection was successfully employed in 1 adult. Total resection was performed in the remaining cases, with 11 successful results, 1 case with partial restoration of motion and 1 case with failure.

SUMMARY

1. The procedure of resection of the elbow joint is discussed in detail and the preservation of the triceps mechanism is stressed. Adequate bony excision and early mobilization are its essential features. In our hands total resection has proved far more satisfactory than partial resection.

2. This operation, in adults, is a satisfactory method for the rehabilitation of a partially or completely ankylosed elbow joint.

3. It is, at present, the treatment of choice for tuberculous arthritis of this joint, in adults, where conservative therapy has failed.

4. Its use is contraindicated in children and in young adults prior to the cessation of the growth period, because of the danger of a deficient functional result or of failure.

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EXTRAFASCIAL APICOLYSIS (SEMB)

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APPROXIMATELY 90 per cent of tuberculous cavities in the lung occur in the upper lobe. Even wide rib resections are occasionally inadequate for closure because the large spherical cavities are converted into longitudinal slitlike spaces which persist in the costovertebral gutter anterior to the transverse processes. These failures have been overcome to a certain extent by resecting the transverse processes in the region of the cavity. Some surgeons have attempted to enhance the collapse through plombage and pressure pads, in spite of which certain cavities continue to resist all efforts at closure. The natural tendency, enhanced where possible by artificial pneumothorax, is for a cavity to heal concentrically. This is often prevented because pleural adhesions may fix the lung to the overlying rigid thoracic cage. The effect of thoracoplasty comes about through the application of two mechanical forces; relaxation and collapse. Both result from a reduction in the size of the thoracic cage. This most often occurs laterally because the base and apex are fixed. The efficiency of the collapse depends upon the extent of the removal of the overlying ribs, the condition of the diseased lung, and the fixation of the mediastinum. Frequently the amount of lateral collapse obtained will prove adequate if the cavity is small. Even though the cavity is not entirely collapsed, the closure of the bronchus leading to it will insure against further escape of tubercle bacilli into the tracheobronchial tree. Early thin-walled cavities will usually heal completely, but older cavities with thick avascular and inelastic fibrous walls probably never heal even though collapsed. Success in dealing with these cavities lies in exerting pressure on them from all directions accompanied by closure of the communicating bronchus. During the past ten years we have at times been disappointed with our failure to accomplish this. Even the most radical sacrifice of ribs has failed to render the sputum negative. It was because of our failures that we decided to employ the extrafascial apicolysis of Semb[1] with the hope that it would in part offer a solution to this problem.

In 1932 Semb[1] first attempted to solve these difficulties. Although numerous types of apicolysis had been suggested and tried with a fair degree of success, it became evident to him that they were inadequate because of their failure to accomplish their purpose. He found that

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the entire apex could be mobilized extrafascially by its separation from three groups of suspensory ligaments. This allowed the apex and surrounding soft tissues to drop downward toward the hilum where they would remain in a collapsed and relaxed condition until the periosteum regenerated new bone. The accompanying rib resections added the necessary lateral collapse. It had another advantage in that it permitted a selective apical collapse. Since the great majority of cavities occur at the apex, it was no longer necessary to sacrifice the lower healthy lung through extensive rib resection in order

Fig. 1.—Shows the chest wall exposed and the division of the serratus upward from the fourth rib.

to produce closure of the localized cavities. This resulted in the preservation of a higher vital capacity, less dyspnea, and less chronic invalidism.

TECHNIQUE

The operation is performed through a paravertebral incision with the patient lying on his side or abdomen, care being taken not to divide the trapezius completely. The scapula is retracted and mobilized by sharp dissection of the insertion of the serratus anterior downward to the level of the fourth rib (Fig. 1). The third, second, and first ribs are resected in order, about two-thirds of the third and almost all of the second and

the first around to the cartilage. Posteriorly the transverse processes are not resected but the articulation between the third and second ribs and their respective transverse processes are separated and the ribs divided far down on the neck (Fig. 2). This is very effective in obliterating the costovertebral gutter and at the same time avoids injury to the intertransverse ligaments which may result in a scoliosis (Fig. 3). In certain instances where the cavity lies high in the apex and close to the costovertebral gutter, it is advantageous to disarticulate the first rib and divide it far down on the neck just as in the lower ribs. This gives an unobstructed view of the apex and its accompanying ligaments which insert in the vertebral bodies. The lysis of this area can then be done under direct vision and with less danger of breaking into the underlying cavities. The usual care must be exercised in avoiding injury to the vessels and nerves in removing the first rib. Semb at this point sepa-

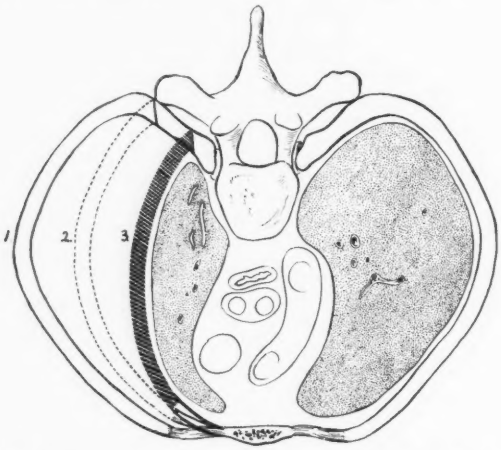

Fig. 2.—Shows a diagrammatic sketch of a transverse section through the thorax. *1* shows the normal contour before resection; *2* shows the contour of the chest after removal of rib segments to the transverse process; and *3* shows the marked reduction of the anteroposterior and transverse diameters of the chest wall when the resections are carried far down on the neck of the ribs.

rates the periosteum of the first rib posteriorly and forward to the attachment of the scalenus anticus muscle. He divides the rib at the transverse process, and with a bone-holding forceps traction is exerted downward and backward exposing the insertion of the scalenus anticus muscle, which can be divided outside the periosteum. The remainder of the rib is then removed to the cartilage. We have preferred to remove the rib first and then to divide the insertion of the scalenus anticus from the periosteum sacrificing the latter which was attached to the anterior rib margin. Semb's method has one distinct disadvantage. The insertion of the muscle is seen only from the posterior surface and if great care is not employed the brachial plexus or subclavian artery may be injured. If the rib is removed first, a

hemostat can be placed on the periosteum at the insertion and an excellent exposure of all important structures can be obtained before division of the muscle.

The apicolysis is started by dividing the fibers between the neurovascular trunk and the pleura. This can usually be done with gauze over the finger tips by gentle pressure forward and downward. This site is chosen because the attachment here is frequently loose. Posteriorly there is seen a well-developed fibrous band of varying density (Sebileau's band) extending from the parietal pleura and overlying endothoracic fascia. It passes upward and backward toward the ver-

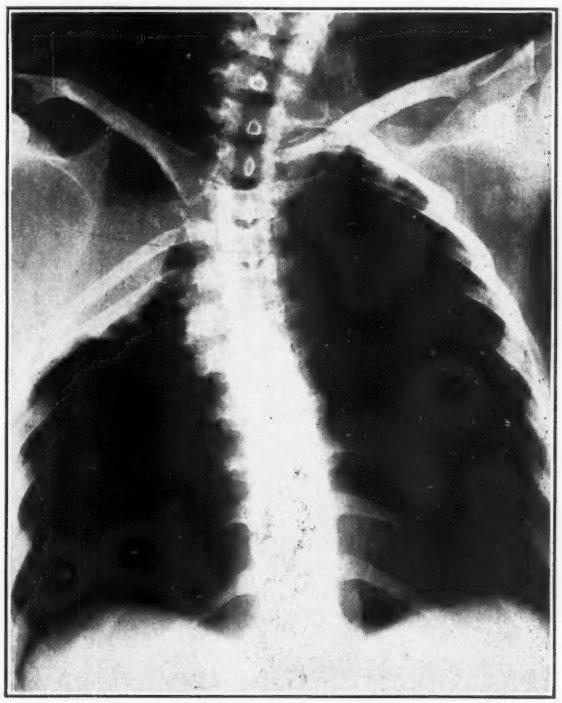

Fig. 3.—Shows the scoliosis which has taken place following a first stage thoracoplasty with apicolysis and removal of the second, third and fourth transverse processes. This we consider a justifiable reason for preserving the transverse processes. The same degree of collapse is accomplished through removal of the ribs far down on the neck.

tebra covering the first thoracic component of the brachial plexus as it emerges from under the neck of the first rib. This is isolated and cut giving immediate exposure of the nerve trunk. Almost invariably another band is seen lying beneath; that is, medial to the nerve trunk, and this is treated in a like manner. The separation is carried forward to the first rib cartilage and the periosteum divided. As the dissection is carried medially, we find the peripleuritis more marked and sharp dissection may have to be substituted to insure safety. When the first transverse process is reached the dissection is carried

downward along the vertebral body. The periosteum and the intercostal bundles are divided at the transverse processes (Fig. 4*B*). Semb suggests the isolation of the intercostal nerves before division

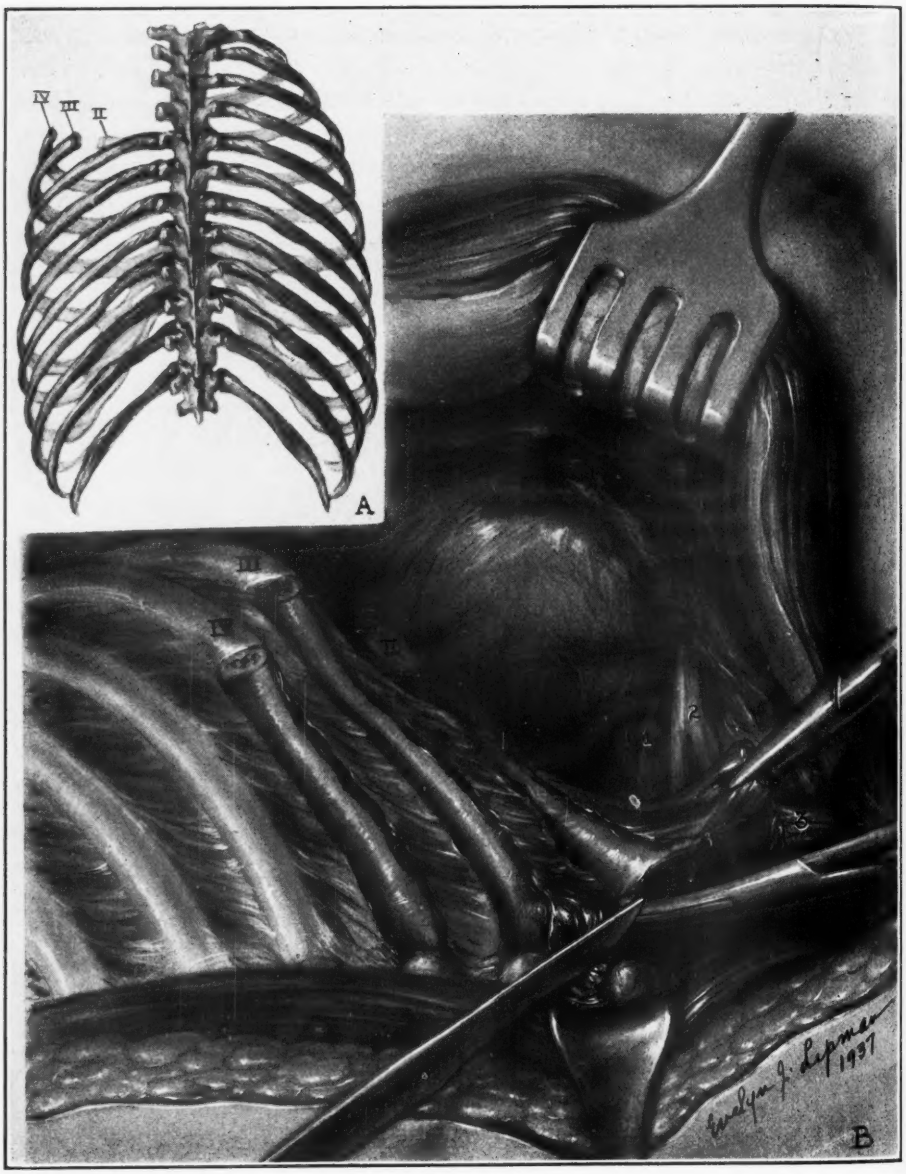

Fig. 4.—Shows (*A*) how graded resections of the upper ribs merely uncap the pleural dome sufficiently for an efficient apicolysis at the same time maintaining adequate anterior support. *B* shows (*1*) vessels; (*2*) plexus; (*3*) divided scalenus posticus. The first intercostal bundle with the periosteum is being divided. The second, third, and fourth ribs will be divided in order as the separation is carried downward.

because of the likelihood of pain if they are included in the ligatures with the intercostal vessels. We have ligated en masse without ill

effect. As the pleura is separated from the lateral surface of the vertebral bodies, it is important to avoid injury to the sympathetic nerve trunk, otherwise a Horner's syndrome may result. There is very little danger of injury in this region unless, due to a mesially placed cavity, a marked peripleuritis is present. If the adhesions are so dense that the apex cannot be safely separated at the level of the first rib, we have proceeded to the level of the third or fourth transverse

Fig. 5.—*B* shows (*1*) a catgut suture being placed through the posterior ends of the divided periosteum and accompanying intercostal bundles preparatory to suture through the periosteum on the anterior surface of the neck of the first intact rib; (*2* and *3*) the neurovascular trunk; and (*4*) the divided scalene muscles. *A* shows the appearance after the sutures are drawn into position forming a rigid apical cap which insures against retraction of the apex to its former position.

process where a line of cleavage can be found. We work upward dividing the periosteum and intercostal bundles as the separation progresses. The apex can always be identified when reached as there are almost invariably one or two pea-sized lymph glands in this region. Until we adopted hunting for a line of cleavage at a lower

level, we encountered an occasional patient where the separation medially was impossible. The dissection is usually very easy on the anterior surface since most cavities lie medially or posteriorly. Anteriorly the pleura is very thin and is easily torn. The internal mammary vessels can be seen and should not be injured. The extent of the apicolysis will be determined by the preoperative condition of the patient, the location and nature of the underlying pathology, the amount of paradoxical breathing, the reaction of the patient to the anesthetic, and the extent of rib resection. In our earlier cases we removed all of the first three ribs around to their cartilages. This was accompanied by marked reactions. Through the suggestion of Semb we changed to a removal of all of only the first rib, less of the

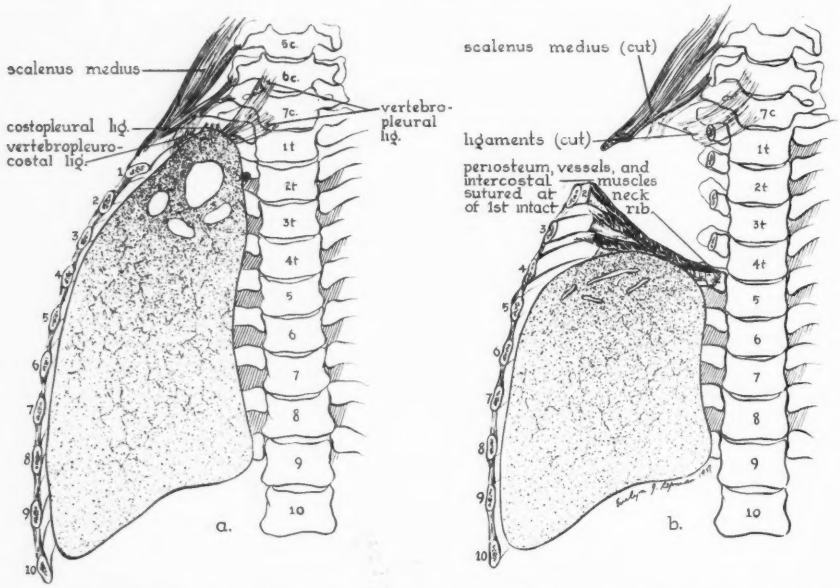

Fig. 6.—*a* shows a diagrammatic sketch of apical structures which must be divided to insure a complete apicolysis. *b* shows the appearance of the lung after apicolysis and fixation of the apex in its new position.

second, and still less of the third and fourth. We then merely uncapped the pleural cupola, at the same time leaving the anterior segments of the second, third and fourth ribs as a support to the anterior portion of the lung. (Fig. 4*A*.) This permitted much less paradox and was accompanied by less shock. The removal of the anterior segments at a later second stage adds the necessary lateral collapse. It is best to err on the conservative rather than on the radical side. Once the apicolysis is complete, Semb closes the wound. We have felt that there was no assurance that the apex would remain in the collapsed position. In our early cases we noted a tendency for the apex to rise an interspace or more within the first four weeks after operation. This was very easily demonstrated by placing a silver clip

at the original site of the apex and another in the apex in its lysed position. We have prevented this rise by suturing the posterior ends of the divided periosteum and muscle bundles to the anterior edge of the neck of the first intact rib, usually fourth or fifth, depending on the extent of the resection (Fig. 5*B*). This is followed by one or two sutures to the upper edge of the rib medially and anteriorly. Where possible a suture is placed through the apical pleura drawing it downward to the neck of the first intact rib. This procedure obliterates the costovertebral gutter (Fig. 7*C*), and it has been especially useful in cases with little pleural reaction where paradoxical respiration was marked. Once the sutures are placed, the intercostal bundles form an apical cap covering the lowered apex (Figs. 5*A* and 6*B*). The periosteum remains intact and through regeneration of new bone there is no chance left for the apex to ascend toward its original position by scar tissue contraction. Overholt[2] advocates the removal of the periosteum, intercostal bundles, vessels and nerves of the first and second ribs at the

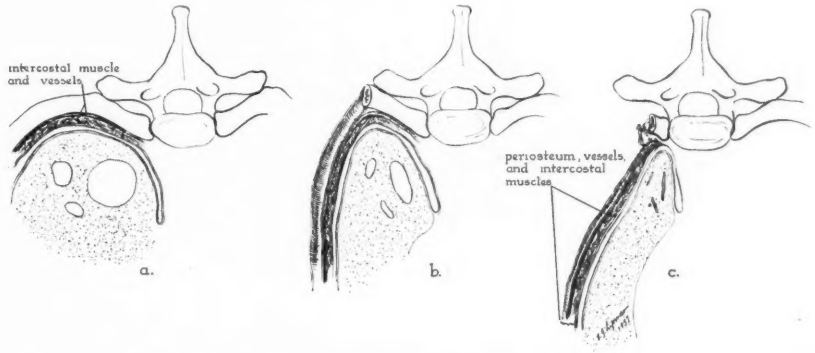

Fig. 7.—*a* shows the normal costovertebral gutter before resection. *b* shows the effect of removal of the rib to the transverse process. *c* shows the effect of disarticulation of the rib and division far down on the neck. Note the increase in anteroposterior and lateral collapse.

time of the apicolysis. We do not find any advantage in this procedure. The preservation of these structures seems advantageous first to form an apical covering which, when sutured, holds the apex in its new position. Second, these structures are frequently firmly attached to the endothoracic fascia as a result of the underlying tuberculous process and to carry out a wide dissection in this area may result in a tuberculous infection of the wound.

Our experiences with the earlier cases in which the bundles were left intact and not sutured showed a definite rise of the apex; therefore, we feel that such a sacrifice of the periosteum would invariably result in a movable apex with paradoxical breathing and retraction toward its original position. Once complete hemostasis is obtained, the wound is closed by muscle approximation with 1-20-day catgut. Drainage may or may not be instituted. We have had better results

without it. This will be discussed later. Semb[1] prefers a catheter drainage for forty-eight hours with frequent aspirations. In certain instances this has definite advantages since there is an excess of serum which forms in the large dead space left remaining (Fig. 8). We have yet to see a single instance where serum accumulation has not occurred. Because of this we have not found it necessary to fill the dead space above the apex with saline solution as advocated by Overholt.[2] If drainage is instituted, the catheter can be connected to a negative pressure apparatus or kept empty by frequent aspirations during the first forty-eight hours. The constant suction is probably better since it permits less meddling and therefore lessens the chance of introducing infection. The apex is fixed by sutures and there is

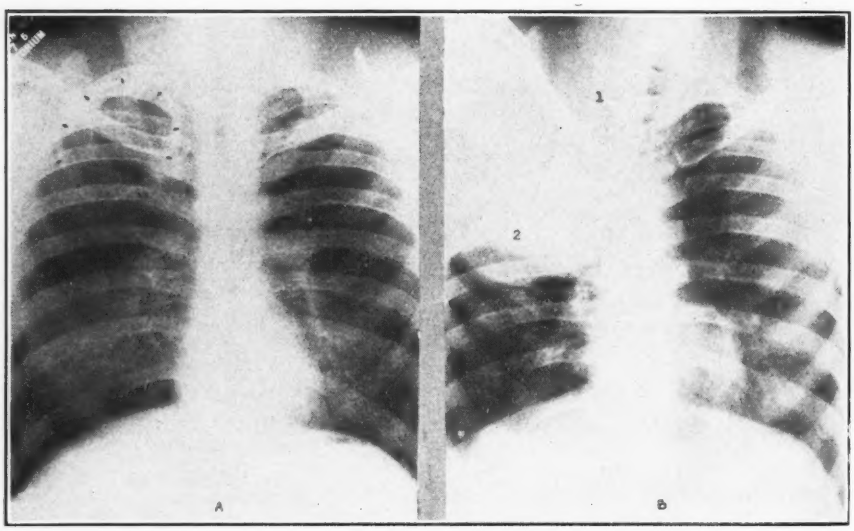

Fig. 8.—*A*, x-ray film of chest showing large apical cavity on the right side; the right hemidiaphragm is not paralyzed. *B*, same patient after operation; there is no evidence of atelectasis. The homogeneous density above is due to a collection of serum in the dead space formed by the lysis of the apex. *1* shows original site of apex; *2* shows the site of the apex after apicolysis.

no danger of its returning to its former position. The average time consumed for the entire operation, once the operator is familiar with the technique, is three-fourths to one hour. Any attempt to shatter records will only result in needless trauma, injury to important structures, and unnecessary complications.

THE SECOND STAGE

In most instances where the cavities have been large and surrounded by thick fibrous tissue walls, a second stage operation has been indicated. We do not feel that this is any argument against apicolysis since the first stage, depending upon the extent of the lysis, cannot be expected to do more than shorten the longitudinal axis of the lung,

thereby providing a certain degree of relaxation and collapse. This is a radical procedure in itself and the lateral collapse through the removal of the anterior rib segments should not be added until a later date. Our experience with this group of cases has shown that the second stage should not be attempted in less than three weeks, preferably four.

As a rule an incision is made through the old scar, but not throughout its entire extent. No effort is made to examine the apex, but instead care is exercised to avoid the opening of the serous cavity which has acted as an efficient tamponade since the previous apicolysis. If the apicolysis is to be increased at this stage, it is necessary to evacuate the cavity in order to divide the intercostal bundle and periosteum of the first intact rib. The anterior segments of the third and fourth ribs are divided anteriorly but not necessarily around to the cartilages. This should be left to another stage. It is not unusual for the cavity which persists to appear as a transverse slit at the site of the first (usually fifth) intact rib near the costovertebral gutter. It is therefore more important to remove the posterior segments of the intact ribs than all of the anterior segments of the ribs above. The extent of the resections will depend on several factors; i.e., the nature of the lesion, its size and location, the reaction of the patient to the first stage, his vital capacity, blood picture, and sedimentation rate. Where these are satisfactory, it has been a practice to remove the necessary length of the fifth, sixth, and seventh ribs. It is definitely advantageous to get a segment of the seventh to prevent an incarceration of the scapula and to remove all possible barriers which might prevent it from falling into the collapsed chest wall. Every patient is treated as an individual problem and it may be found necessary to add a third and even fourth stage operation if his condition will not permit the necessary amount of rib removal at the second stage.

ANTEROLATERAL STAGE

With large upper lobe stiff-walled cavities it is necessary to remove all of the anterior segments of the upper four or five ribs. This operation is done as a third stage and removes all support from the anterolateral chest wall, thereby insuring the maximum collapse through the proper usage of shot bags and pressure pads. The incision employed is along the lateral border of the pectoral muscle on women, but on men we use a vertical parasternal incision extending from the first rib cartilage downward as far as necessary. The fibers of the pectoralis major are separated and the cartilages and the remaining anterior rib segments are removed flush with the sternum. The first rib cartilage is not disturbed. Its removal has not been found necessary since at the time of the apicolysis the periosteum of the first rib

was divided anteriorly and allowed to follow downward with the apex. It therefore offers no barrier to collapse. This saves time since its removal is more difficult than the other cartilages.

REVISION OPERATIONS

It is generally accepted that there are certain cavities which will resist all the collapse measures which we have available. There are a small number of these if we make a critical analysis of our failures. The usual causes are: the removal of an inadequate amount of rib in the region of the cavity, too few stages, or the inefficient use of pressure pads. We have encountered several of these patients and realized that further surgery was needed. The cases chosen were those who had had adequate rib removed but in whom cavity closure was unsuccessful because the cavity had been converted from a rounded one into a narrow longitudinal slit nestling in the costovertebral gutter alongside the bodies of the upper three or four dorsal vertebrae. In this series it was obvious that the maximum amount of pressure applied laterally had been obtained and that the cavity was suspended from the apex due to its fixation through ligamentous attachments. To overcome this and to promote longitudinal collapse, a paravertebral incision is made through the old scar. The scapula is separated from the chest wall by sharp dissection. Since there is a distortion of the normal anatomic relations, especially in the region of the brachial plexus and the regenerated first rib, it is much safer to start at the level of the third or fourth ribs near the vertebrae. The regenerated segments are removed until the first rib is reached. At times this will allow adequate orientation to proceed with its removal providing the scalene muscles have not pulled the regenerated periosteum high into the neck. If this condition exists, it is much simpler to start at the level of the fourth rib at its posterior end and find the line of cleavage in the endothoracic fascia. By dividing the intercostal bundles and periosteum, the line of cleavage can be followed upward. The apex is exposed as an elongated cone pointing upward. The greatest care must be exercised as the lysis is carried out since the cavity may be opened resulting in numerous complications (to be discussed later). If a marked peripleuritis is present, the lysis should be done by sharp dissection. When the ligaments at the apex are divided, the operator must be on guard against injury to the first thoracic component of the brachial plexus. It is possible at times to complete the lysis without disturbing the regenerated first rib. If it is left, no barrier to collapse is offered by its presence because the lung containing the lesion will be displaced downward. Removal of the rib is much easier after the lysis has been completed because all important structures can be easily visualized. At this stage we suture the posterior ends of the divided intercostal bundles and periosteum to the first intact rib

the same as is done in a first stage apicolysis. These sutures serve the same purpose; namely, preventing a rise of the apex to its former position during healing. The wound is then closed without drainage. The revision operation is much more tedious than the primary one because of the disturbed anatomic relations. It, therefore, requires one to two hours operating time. From our limited experience, it has been found that revision operations are next to technically impossible if nine to twelve months have not elapsed following the primary stage. This allows sufficient time for the regenerated ribs to become thoroughly calcified. Before this, the incompletely regenerated periosteum is fibrous and cannot be separated. The only recourse then is its removal, which sacrifices the one possible chance for a rigid support of the underlying collapsed lung.

POSTOPERATIVE CARE

The care of the patient following apicolysis is most important since the procedure is accompanied by more shock than following an ordinary first stage thoracoplasty. This occurs as the result of a combination of several factors. The patient has been submitted to a more radical procedure entailing a much wider dissection with a disturbance of normal physiologic relations. The wound is exposed for a longer period and the blood loss is greater. All of our patients suffered from shock following operation. The intensity ranged from a mild to a severe degree. Our criteria for shock are based on a low blood pressure, systolic below 85 mm. Hg, accompanied by a rapid pulse, over 100, and a pale, cold, leaky skin. We have attempted to prevent this by the administration of rectal and intravenous fluids during the operation. The first evidence of shock often manifests itself when the patient is transferred from the operating table to his bed. This occurs whether the operation has been performed in the prone or lateral position. We have always placed the patients on the bed in the supine position since there is less pain and the respiratory exchange is most efficient in this position. Intrapharyngeal oxygen is used routinely after each first stage. The nasal tube is inserted by the anesthetist while the patient is on the operating table; the oxygen flow is regulated between five and seven liters per minute. This is continued for the first twenty-four to forty-eight hours after which it is gradually reduced until the patient is weaned. If the degree of shock is marked, heat is applied through the use of an electric cradle. Intravenous glucose and subcutaneous saline are administered first. If these do not succeed in maintaining the blood pressure, a transfusion is given. The patient's position is frequently changed and we insist on his coughing to rid the tracheobronchial tree of any secretions which may have been squeezed from the cavity during the lysis. This is important particularly in cases where the diaphragm on the

operated side is fixed. Unless these secretions are removed, an atelectasis may result. The usual drugs are employed to control pain. These are used in as small doses as possible in order not to suppress the cough reflex. A bedside x-ray film is taken during the first twenty-four hours to determine if any atelectasis has occurred. This is followed by more films to provide a close check on any important change in the pulmonary pathology which may manifest itself later. Compression pads are used as soon as they can be tolerated by the patient. The wound is watched closely for evidence of increased pressure within the dead space. This manifests itself in the form of a quickened respiratory rate, pain in the arm on the operated side, and at times by a bulging at the base of the neck anteriorly. If the pressure is sufficient to cause these signs and symptoms, a needle is inserted in the interscapular space at a distance from the line of incision and the excess serum removed. This is always cultured to determine the presence or absence of microorganisms. The pain following apicolysis is less than that encountered following ordinary thoracoplasty. This is probably due to the division of the upper intercostal nerves. The postoperative care following the second or anterolateral stages is essentially the same as following the first stage. These, however, are accompanied by less shock and discomfort. The blood picture should be checked closely following each stage since the cumulative effect of previous stages often lowers the hemoglobin remarkably. This is controlled with frequent small blood transfusions.

ANESTHESIA

The problem of anesthesia for these patients is a complicated one. A mutual understanding between the surgeon and the anesthetist is imperative. Waters and his staff have cooperated with us in solving these difficulties and this has resulted in the evolution of a technique which is satisfactory for the patient as well as the anesthetist and the surgeon. Waters[3] feels that an acquaintance with the use of a given combination of drugs and a certain skill in the individualization of their administration is most important. He states that no one agent or technique solves the problem for all patients or for every surgeon or anesthetist. Coughing, hyperpnea, and paradoxical breathing are to be avoided since they not only increase the difficulty of the surgical procedure but also increase the liability of the spread of infected secretions into clean areas of the tracheobronchial tree and possible rupture of the lung. Excessive bleeding is to be avoided. A depression of the cough reflex for a period longer than the time consumed for the operation is undesirable.

All of the following gases: nitrous oxide, ethylene, cyclopropane, and ether in moderate dosage probably increase peripheral blood flow. This results in a greater loss of blood during the operation than when

peripheral or spinal block anesthesia, chloroform, or tribromethanol are used. Certain unsatisfactory accompaniments with the usage of the latter group, such as prolonged circulatory and respiratory depression, have seemed to us to overshadow the few possible advantages they may possess.

Moderate premedication with morphine and scopolamine followed by skillful, quiet induction of the anesthesia by inhalation has, in our hands, seldom resulted in disturbances of respiration. The use of the carbon dioxide absorption technique has proved desirable since it offers the patient a warm, moist atmosphere. Absolute freedom from respiratory obstruction is essential, and with few exceptions we have found a pharyngeal airway adequate. This permits a lighter plane of anesthesia than is required for tracheal intubation. A slow induction with nitrous oxide or cyclopropane with a small face mask affords little dead space. An atmosphere is employed which simulates the oxygen content of room air as closely as is consistent with adequate oxygenation of the blood and tissues. This will, in a majority of cases, produce anesthesia without cough or hyperpnea.

Certain precautions in the application of carbon dioxide absorption technique are important. We believe that a minimum disturbance of the oxygen and carbon dioxide balance of the patient's blood and tissues gives the best results. Oxygen tension in the anesthetic atmosphere, in excess of that sufficient to avoid bad color and disturbances of the pulse rate and blood pressure, has at times seemed to give a false sense of security during the operation and has been followed by disappointment in the immediate postoperative period. Physical control of intrapulmonary pressure by moderate and carefully individualized distention of the thin rubber breathing bag will usually control any tendency to paradoxical respiration.

ANALYSIS OF CASES

This report consists of an analysis of sixty-five cases which have had extrafascial apicolysis. Forty-four of these have been operated upon at the Wisconsin General Hospital and twenty-one at the Wisconsin State Sanatorium during an eighteen-month period from January, 1936, to July, 1937. Eight additional cases have undergone revision operations with extrafascial apicolysis.

INDICATIONS FOR OPERATION

Our indications for this procedure on the sixty-five primary cases have been rather broad. We have used it with apical cavitation, particularly in large single or multiple cavities surrounded by thick inelastic fibrous tissue walls and atelectatic indurated lung parenchyma. It was also used when the disease was confined to the apex since it permitted the preservation of the uninvolved portion of the lung. Except

in one instance, we have not employed the procedure where apical cavities were not demonstrable because the added hazard was not deemed justifiable. There were certain clinical, laboratory, and x-ray findings which were found to be of some prognostic significance. These have been correlated with the convalescence which has been divided into three types: First, *the easy* in which there was no more than the ordinary postoperative febrile reaction on the second and third days, little or no dyspnea, no increased toxemia, and no necessity for postponement of the second stage. Second, *the moderately severe* in which there was a short-lived dyspnea, transient increase in toxemia during the first week after operation, and where it was necessary to delay the second stage for a period of not over six weeks. Third, *the stormy* where there was a severe and prolonged postoperative febrile reaction, moderate to severe dyspnea requiring oxygen for at least one week or more after operation, marked toxemia with or without x-ray evidence of a spread of the tuberculous process, and where the second stage had to be delayed for a period of six weeks to six months.

Cause of Death in Sixty-Five Patients (See Table I).—The argument often used against the performance of a given surgical operation is frequently directed at the accompanying mortality. This was one of the chief early objections to extrapleural thoracoplasty. It has been practically dispelled, however, with an increasing experience which has taught us to fit the operation to the patient and not the patient to the operation. This attitude will, we believe, enable us to continue to reduce the mortality following this more radical procedure.

TABLE I

CAUSE OF DEATH IN SIXTY-FIVE CASES

AGE AND SEX	CAUSE	POSTOPERATIVE DAY
39 M	Cardiac dilatation	1
29 M	Streptococcus pneumonia	8
42 M	Tuberculous wound infection and hemorrhage	60
31 F	Pulmonary thrombosis	6
37 F	Tuberculous pneumonia on opposite side	6
7.6% Total mortality		

Causes of Complications Which Were Unpredictable (See Table II).—Certain unpredictable complications will always occur in cases of this type. Although they may not always be of a serious nature, they are usually the cause of a fair percentage of the deaths.

Relationship of Infection to Drainage (See Table III).—After performing several of these operations it soon became evident that we were getting an extraordinarily high percentage of infections. At the time there were a large number of acute respiratory infections among our operating room staff. We attempted to eliminate this source of contamination by excluding all assistants and nurses from the operating

TABLE II

CAUSES OF COMPLICATIONS WHICH WERE "UNPREDICTABLE"

NO. OF PATIENTS	CAUSE	OUTCOME
4	Severe wound infection	Recovered
1	Streptococcus pneumonia	Died
1	Hemorrhage after cavity was opened at time of operation	Died
1	Cystitis and bilateral phlebitis	Recovered
1	Cardiac dilatation	Died
1	Diabetes and severe wound infection	Still in hospital
1	Tuberculous empyema	Recovered
1	Pulmonary thrombosis	Died
1	Heart failure (digitalis)	Recovered
1	Wound infection and asthma	Recovered
13 Total		Dead, 4 Recovered, 8 Still in hospital, 1

room if they had an upper respiratory infection. Only those actively engaged in the operation were allowed in the operating room. These precautions resulted in a marked reduction in the number of infections, but did not succeed in entirely eradicating them. Our attention was then directed to the fact that a much higher percentage of infections occurred in the patients in whom drainage was instituted. For this reason we have now eliminated all drainage following apicolysis with the result that we are getting an increasingly small number of infections.

TABLE III

RELATIONSHIP OF INFECTION TO DRAINAGE

NO. OF STAGES		CLEAN	INFECTED
	A		
30	One stage with apicolysis drained	23	7 (23.0%)
35	One stage with apicolysis not drained	32	3 (8.5%)
65	Total	55	10 (15.0%)
	B		
26	Second, third and anterolateral stages drained	22	4 (15.4%)
49	Second, third and anterolateral stages not drained	47	2 (4.0%)
75	Total	69	6 (8.0%)
	A and B		
56	Drained	45	11 (19.6%)
84	Not drained	79	5 (5.9%)
140	Total*	124	16 (11.4%)

*Ten operations that were done through previously infected fields are not shown in this table.

Causes of Complications Which Were Predictable (See Table IV).—Certain complications can be avoided if due care and diligence are exercised in the choice of cases for surgery. These we have called predictable since in the majority of instances their occurrence could have been greatly reduced or entirely avoided if sufficient significance had been attached to the laboratory and clinical data at hand pre-

operatively. On the other hand, it must be remembered that the bad risk patient is doomed to chronic invalidism or early death if surgical collapse is not instituted. The number of operative stages will have to be increased and each stage lessened in extent, often being accompanied by a predictable stormy convalescence or even death. Regardless of this, it seems justifiable to attempt to salvage what few we can from a certain fatal outcome.

TABLE IV

CAUSES OF COMPLICATIONS WHICH WERE "PREDICTABLE"

NO. OF PATIENTS HAVING A STORMY COURSE	
2	Spread of tuberculous process to opposite side (one dead)
6	Prolonged atelectasis with questionable tuberculous pneumonia
4	Tuberculous toxemia
1	Atelectasis and spread of tuberculous process to the base
1	Spread of tuberculosis to both sides
1	Tuberculous pneumonia
15	Total

The Relationship of Diaphragmatic Paralysis and Postoperative Atelectasis (See Table V).—A study was made of forty-four patients.* All were fluoroscoped to determine if there was a true diaphragmatic paralysis present. In one instance the paralysis was questionable because of a thickened pleura and accompanying fibrosis of the underlying lung. Two with and five without diaphragmatic paralysis had preoperative atelectasis and two others with questionable paralysis also had preoperative atelectasis. These were not used in our calculations. Of the thirty-five patients in which we were sure as to the mobility of the diaphragm, postoperative atelectasis was almost twice as frequent in the cases with preoperative diaphragmatic paralysis.

TABLE V

RELATIONSHIP OF DIAPHRAGMATIC PARALYSIS TO POSTOPERATIVE ATELECTASIS

	NO. OF PATIENTS	DEVELOPED ATELECTASIS AFTER FIRST STAGE	DEVELOPED ATELECTASIS AFTER SECOND STAGE	PER CENT AFTER FIRST STAGE
16	with diaphragmatic paralysis	8	1	50.0
19	without diaphragmatic paralysis	5	1	26.5
1	with questionable diaphragmatic paralysis		1	
2	with diaphragmatic paralysis with complete preoperative atelectasis			
5	without diaphragmatic paralysis with complete preoperative atelectasis			
1	with questionable diaphragmatic paralysis with complete preoperative atelectasis			
44	Total			

The first signs and symptoms of atelectasis usually occurred on the third or fourth postoperative day. There were signs of increased

*Only forty-four of these cases were considered since the remaining twenty-one were done in the Wisconsin State Sanatorium where it was impossible to obtain routine bedside x-rays postoperatively.

toxemia and often pain over the collapsed area. The temperature was usually slightly elevated; dyspnea and cyanosis appeared particularly in those patients with a low vital capacity. The lung field became opaque to x-ray (Fig. 9*B*). The sputum, which was temporarily increased after operation, diminished greatly or became absent. On physical examination the heart could be found to have shifted to the collapsed side, depending upon the flexibility of the mediastinum. The percussion note was dull to flat. Breath sounds were greatly diminished to absent; if present, usually bronchial in character and heard only over the hilum. If the collapse was uncomplicated by a spread of the tuberculous process or infection, it gradually cleared over a period of two to three weeks. X-rays showed the density clearing at the hilum and in the larger bronchi first. This was accompanied by the appearance of râles here. The sputum which was scanty or entirely absent became copious for the next two to three days. The patient's general condition improved, the appetite increased, and the pulse and temperature returned to normal. Usually the lung entirely cleared in three to four weeks (Fig. 10).

From these figures we assume that preoperative diaphragmatic paralysis was a factor in the production of a postoperative atelectasis. The mechanics are not thoroughly understood. Theoretically it may be said that the pistonlike action of the diaphragm is a most important asset in keeping the bronchial passages free of secretions. If this action is lost, the overactivity of the unopposed intercostal muscles is inadequate. This may be true in a certain group of cases, but does not answer the question satisfactorily since 26.5 per cent of those with normal diaphragmatic movement were victims of the same complication. Some of these patients may have developed this condition because of a stenosed bronchus or through the aspiration of a large amount of thick tenacious material which could not be expelled under any conditions. Another factor conducive to the development of subsequent atelectasis is the weakening of the chest wall through rib resection and paradoxical respiration. These we have tried to eliminate by the removal of shorter segments of the fourth, third, and second ribs at the time of the apicolysis. The paradoxical respiration has further been combatted by suturing the apex and surrounding structures in their new position (see Technique). This complication has occurred in both groups despite a careful preoperative emptying of the tracheobronchial tree by coughing and light anesthesia during the operation which will allow cough immediately after. We are unable to say at this time whether this condition occurs more frequently after apicolysis than after an ordinary first stage thoracoplasty.

Relationship of Atelectasis to Postoperative Convalescence (See Table VI).—The question of postoperative atelectasis is debatable since certain authors have failed to recognize it as a complication. Others feel

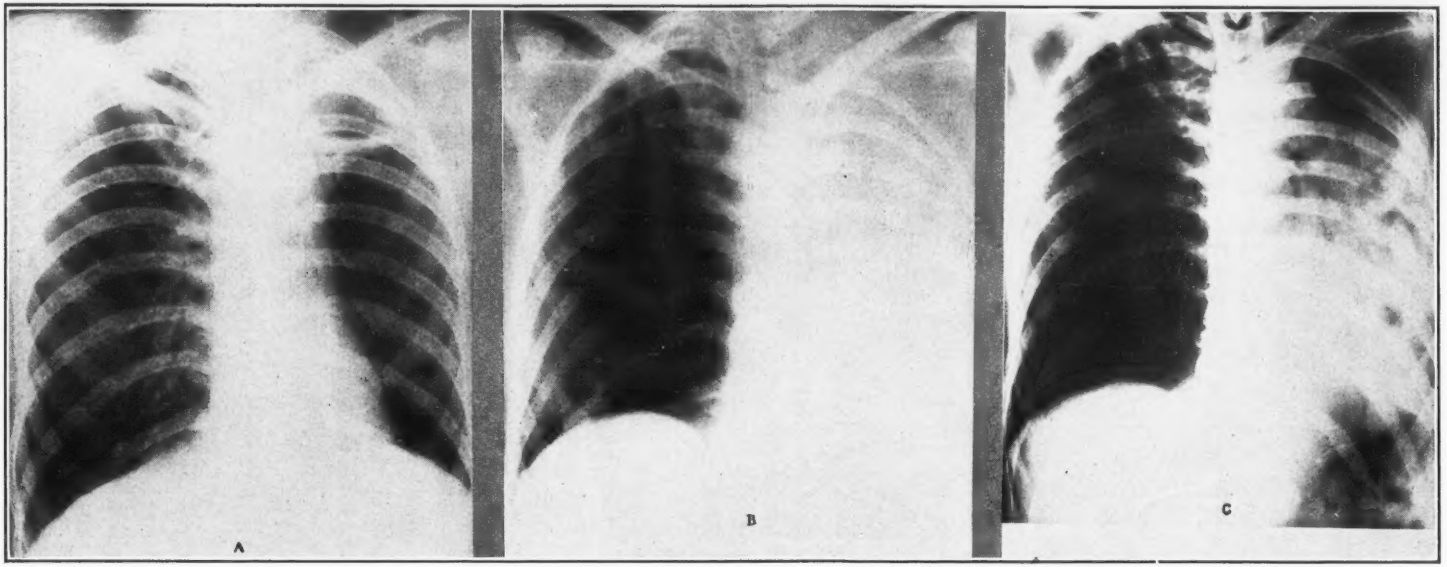

Fig. 9.—*A*, x-ray film of chest showing large apical cavity on the left; the left hemidiaphragm has been paralyzed. *B*, same patient forty-eight hours after operation. Note homogeneous density throughout the left lung field due to atelectasis. *C*, same patient two weeks later. The lung field is clearing; the density disappears as the lung becomes aerated. The rarefied area above simulating a cavity is due to air trapped in the dead space above the apex.

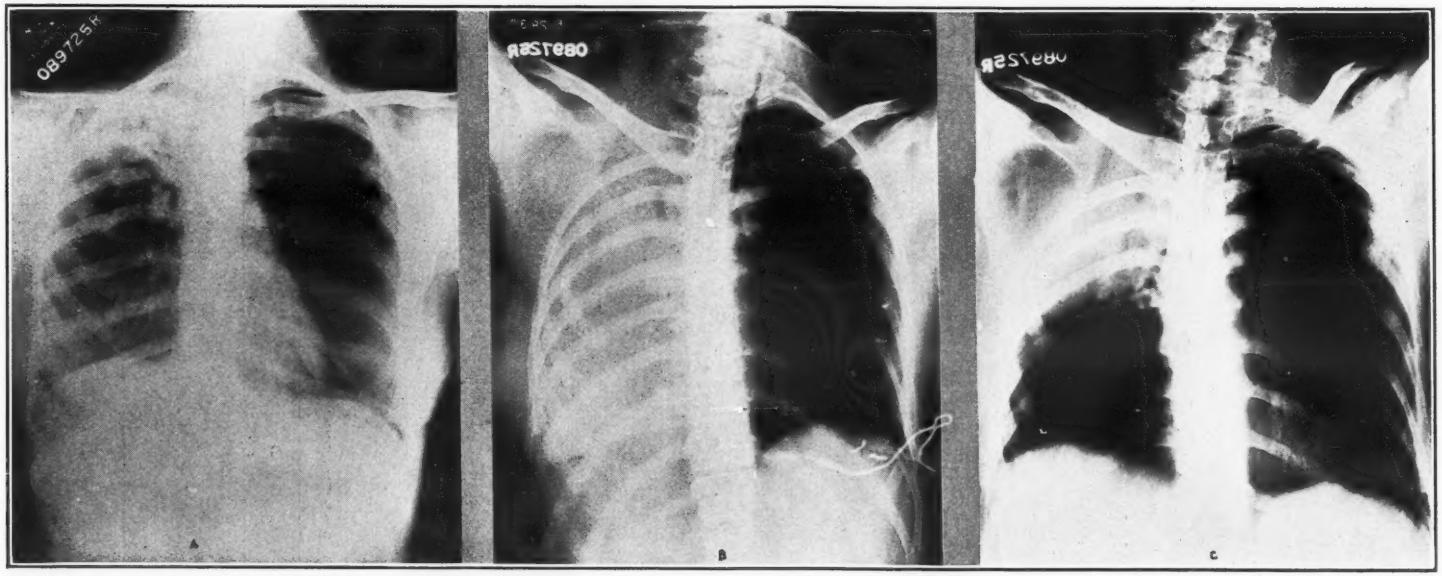

Fig. 10.—*A*, x-ray of chest showing right upper lobe cavity with fibrosis. *B*, shows the development of atelectasis throughout the operated lung. *C*, shows complete clearing of uncollapsed portion of the lung three weeks after operation. This patient had a moderately stormy post-operative course necessitating delay of the second stage operation.

that it is rare and that what is called atelectasis is nothing more than a so-called pleural reaction. To check this we have made many thoracenteses to determine if a pleural exudate was present and in every instance no fluid was obtained. After following these cases carefully by physical examination and x-ray, we noted a clearing of the lung parenchyma in most instances. Because of our experience we feel that the cause of a stormy convalescence is frequently misunderstood and the etiology erroneously attributed to an autotuberculinization, spread of the tuberculous process, or to a tuberculous pneumonia, when in reality it is due to an atelectasis. This complication very frequently produces a stormy postoperative course.

TABLE VI

RELATIONSHIP OF ATELECTASIS TO POSTOPERATIVE CONVALESCENCE

NO. OF PATIENTS		TYPE OF CONVALESCENCE EASY	STORMY
13*	developed postoperative atelectasis	3	10 (77.0%)
19	did not develop postoperative atelectasis	18	1 (5.5%)
7	had preoperative atelectasis	4	3 (43.0%)
39	Total	25	14 (36.0%)

*Of these 13 patients, 8 (62%) had preoperative diaphragmatic paralysis. Five were taken out because they had unpredictable complications.

The Effect of Active Progressive Contralateral Tuberculosis on Convalescence (See Table VII).—The evaluation of patients who are possible candidates for thoracoplasty is not always easy since frequently the picture is complicated by the presence of contralateral disease. We are unable to predict what the lesion in the opposite lung will do after surgery for closure of the original focus. The shock of the operation along with the temporary lowering of the patient's resistance and the increased burden thrown upon the better lung may result in a rapid spread of the disease. The more acute and widespread the disease in the better lung, the more often this will occur.

TABLE VII

EFFECT OF ACTIVE PROGRESSIVE CONTRALATERAL TUBERCULOSIS ON CONVALESCENCE

NO. OF PATIENTS		TYPE OF CONVALESCENCE EASY	STORMY
6	with active contralateral tuberculosis	2	4 (67%)
45	with quiescent or no contralateral tuberculosis	34	11 (24%)
1	with questionable contralateral tuberculosis	1	
52	Total	37	15 (36%)

Showing the Effect of Vital Capacity on Postoperative Course (See Table VIII).—Since the vital capacity was taken routinely on all patients preoperatively, we have compared these findings with the type of convalescence. In each instance a spirometer was used. The percentage

of normal was calculated for each patient. This was done because the measurement of volume alone is unsatisfactory. A vital capacity of 1 liter for one individual might be 50 per cent of the normal, while in another it would be only 25 per cent of the normal. For several years we have considered a vital capacity of less than 35 per cent as significant of a dangerously low respiratory reserve. We have tried to overcome the associated dangers by doing less at each operation and by increasing the number of stages. We have also realized that many factors must be considered in evaluating the vital capacity readings. If all these factors are kept in mind, we feel that vital capacity readings are of definite value.

TABLE VIII

SHOWING THE EFFECT OF VITAL CAPACITY ON POSTOPERATIVE COURSE

NO. OF PATIENTS	TYPES OF CONVALESCENCE			
	EASY		MODERATELY STORMY OR STORMY	
11 vital capacity less than 35%	5	(45%)	6	(55%)
39 vital capacity over 35%	31	(80%)	8	(20%)
2 vital capacity not recorded	1		1	
52 Total	37	(72%)	15	(29%)

Effect of Sedimentation Rate on Convalescence (See Table IX).—The blood sedimentation rates were checked on these patients and they were classified into three groups: those with a fall of 0 to 15 mm. in one hour *slow,* 15 to 24 mm. *medium,* and over 25 mm. *rapid.* These were in turn compared with the type of convalescence to determine if there might be any possible connection. This comparison shows that the slower the sedimentation rate, the more likely the patient is to have an easy convalescence. It also demonstrates that some importance should be attached to this laboratory procedure.

TABLE IX

EFFECT OF PREOPERATIVE SEDIMENTATION RATE ON CONVALESCENCE

NO. OF PATIENTS	SEDIMENTATION RATE	TYPE OF CONVALESCENCE		
		EASY	MODERATELY STORMY OR STORMY	
16	Rapid	9	8	(47%)
22	Medium	17	5	(23%)
13	Slow	11	2	(15%)
52 Total		37	15	(29%)

The Relationship of the Leucocytic Picture to the Postoperative Convalescence (See Table X).—A careful record was kept of the preoperative leucocyte counts. This was made as simple as possible since the monocytes were not always counted. If the polymorphonuclears were over 70 per cent and the lymphocytes below 20 per cent, the picture was considered bad. When the polymorphonuclears were above 70

per cent and the lymphocytes above 20 per cent, or the polymorphonuclears below 70 per cent and the lymphocytes below 20 per cent, it was considered fair. If the polymorphonuclears were below 70 per cent and the lymphocytes above 20 per cent, it was considered good. Although this has not been accepted as a classification, we have checked it against the type of convalescence and found that it worked out as expected. We hope to use it in the future as a relatively simple method which will help evaluate the condition of the patient.

TABLE X

RELATIONSHIP OF THE LEUCOCYTIC PICTURE TO THE POSTOPERATIVE CONVALESCENCE

NO. OF PATIENTS	LEUCOCYTIC PICTURE	TYPE OF CONVALESCENCE EASY	STORMY
9	Bad	2	7 (78%)
15	Fair	12	3 (20%)
28	Good	23	5 (18%)
52 Total		37	15 (29%)

The Effect of Operation on Cavity Closure (See Table XI).—X-ray films were taken after each operation to determine the effect of each stage on the reduction in size of the cavity. It was evident from these studies that the apicolysis alone did not always succeed in closing the cavity. Other stages had to be performed to add the necessary lateral collapse. In many instances cavities appeared closed to the ordinary flat plate but were found to be open following an overexposed Bucky film. As seen in the table, the percentage of cavities closed was high except in those patients where complications arose which prevented further surgery.

TABLE XI

EFFECT OF OPERATION ON CAVITY CLOSURE

NO. OF PATIENTS	
65	Had apicolysis
5	Died
60	Survived
54	Surgery completed or suspended
53	Cavity present before operation
47 (88.7%)	Cavity closed
6*(11.3%)	Cavity open

*3 too ill for completion of the contemplated number of stages.
1 had apical cavity closed but basal cavity open.
1 cavity open because of delay of later stages due to wound infection.
1 cavity was thought to be closed but later x-rays demonstrated that it was still open.

Relation of Cavity Closure to Sputum (See Table XII).—The closure of a tuberculous cavity does not mean that the patient is going to show a negative sputum. The walls of the cavity may be brought into apposition but the tubercle bacilli continue to escape through a communicating bronchus. If the bronchus is kinked simultaneously with

the cavity closure, the sputum will become negative. We have seen cavities with thick fibrous walls adequately collapsed but no tendency to heal as shown months later at postmortem. It seems more important that the communicating bronchus become closed in old cavities than in the new ones which are still capable of closing and healing with a sufficient amount of relaxation supplied through operation. In this group of cases the ratio of negative sputum ran very close to the

TABLE XII

RELATION OF CAVITY CLOSURE TO SPUTUM EXAMINATION

NO. OF PATIENTS	
	Before Operation
53	Cavity present
51	Cavity open, sputum +
	After Operation
41 (80%)	Cavity closed, sputum -
2 (4%)	Cavity closed, sputum -, guinea pig +
1 (2%)	Apical cavity closed, basal cavity open, sputum -
2*(4%)	Cavity closed, sputum +
5†(10%)	Cavity open, sputum +

*In 1 of these patients the cavity was closed on the operated side, but had an open contralateral cavity; sputum +. The other patient had no demonstrable residual cavity; sputum +.

†In 3 of these patients the surgery was suspended because of their poor condition. In 1 patient surgery was delayed beyond the optimum time because of wound infection.

number of closed cavities. The reasons for failure are enumerated. In a small percentage of cases where this discrepancy cannot be satisfactorily explained, an examination should be made to determine the presence of a tuberculous bronchitis or the possibility of an active contralateral lesion.

REVISION OPERATIONS (RESULTS)

Eight patients received revision operations with apicolysis. These were necessary because the primary procedures had failed to close the cavities. The mortality in this group was high. Three patients died directly or indirectly as the result of the operation. In one case the cavity was opened accidentally during the apicolysis. This resulted in a severe mixed infection. The convalescence was stormy from the outset. A grave toxemia associated with a high fever, rapid pulse, and an increasing anemia persisted until death, which occurred at the end of six weeks. Just before death there was a severe hemorrhage from the wound which demanded immediate surgery. Upon exploration the entire dead space above the apex and all of the surrounding structures were involved in a widespread tuberculous infection. An intercostal vessel had been eroded and was responsible for the bleeding. While doing the apicolysis on the second patient, the cavity was accidentally entered. It was sutured and remained closed. The wound healed but the patient died four months later of an advanced

myocardial degeneration and spread of the tuberculosis to the opposite lung. A revision operation had been attempted on the third patient six months previously. It had to be suspended because of the shock which followed the partial removal of the regenerated segments. At the time of the second revision these segments were completely removed and an apicolysis started. In one over-enthusiastic attempt to do a very radical apicolysis, the cavity was accidentally opened. This was sutured and the wound closed but the patient never regained consciousness. He developed a hemiplegia presumably from an embolus and died twenty-four hours later. An autopsy was not permitted.

Five patients survived and four enjoyed an easy uncomplicated convalescence. In three the cavity was closed and the sputum became negative. In one patient the cavity was apparently not closed even though it was not visible on x-ray. The sputum was negative on smear but positive on guinea pig inoculation. Further surgery is now being instituted. In the other patient the cavity was accidentally opened at the time of operation. The immediate postoperative course was stormy. At this time the wound is healing satisfactorily and the patient's condition is good; his cavity is not visible; and his sputum is negative.

In our limited experience with revision operations of this type, the results have not been as satisfactory as we have desired. The outstanding and most serious complication has arisen following the accidental opening of the incompletely collapsed cavity. In checking this group we have found that this accident has always occurred after the apex had been freed above and just when we were trying to increase the efficiency of the collapse by separating the medial side of the lung from the third or fourth dorsal vertebrae. Invariably the residual cavity has been found just beneath the visceral pleura and so intimately attached to the vertebral bodies that separating was impossible without tearing the lung. Because of these constant findings we are now content to conclude the separation at this point.

The secondary hemorrhage which occurred in two of these cases was most dramatic and proved that no attempt should be made to close the wound with any kind of tube drainage. If this is done exudate collects within the wound cavity and enhances the spread of the tuberculous process in the surrounding tissues. These wounds should be packed widely with vaseline gauze which will not allow any pooling of the infected exudate. This pack should be changed at least once each day. If this is not done, the patient's temperature immediately rises. Dakin's solution has not been used because of the danger of reopening the sutured cavity. Saline has been found to be useful.

SUMMARY

This report includes sixty-five cases of thoracoplasty with extrafascial apicolysis (Semb) and eight revision operations. A study of certain preoperative findings was made to determine their value as an aid in the selection of cases for surgery. Since the procedure is rather new, the complications were frequent in the earlier cases. These have been greatly reduced with an increasing experience, a more careful selection of cases and the proper timing of the operative stages. The percentage of cavity closures and sputum conversions has been gratifying. It is too early to make a definite statement as to the final outcome, but it is encouraging to know that an increasing number are already being discharged from the sanatoria as arrested cases. The group of revision operations is too small to evaluate except that the most serious complication to be encountered is the accidental opening of the tuberculous cavity. This is best treated by packing the wound wide open to insure adequate drainage.

We wish to express our appreciation to Dr. E. R. Daniels for his cooperation in compiling the data on the group of patients operated upon at the Wisconsin State Sanatorium.

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Editorials

The Extrahepatic Biliary Tract as a Functional Unit

THE year just ended has witnessed the publication of several studies dealing with the comparative anatomy and physiology of the gallbladder and the sphincter of Oddi. Among these the article by Schmidt and Ivy[1] is of special interest as presenting, for the first time, an attempt to classify the whole extrahepatic biliary tract of higher vertebrates in terms of functional types. This is no mere rationalization but a synthesis of experimental data from some eighteen species, involving a study of the total output and concentration of hepatic bile, the anatomic capacity of the gallbladder, its concentrating power, and the sphincteric resistance exerted at the choledochoduodenal junction. The four types are characterized as follows:

1. *Gallbladder absent;* large output of dilute hepatic bile; sphincteric resistance low (pocket gopher, rat, pigeon, horse).

2. *Gallbladder of low physiologic capacity,* due to large output of dilute hepatic bile and ability of gallbladder to concentrate bile from only two to six times; sphincteric resistance low to moderate (guinea pig, rabbit, African bush rat).

3. *Gallbladder of high anatomic but low physiologic capacity,* due to the small output of concentrated hepatic bile and the inability of the gallbladder to concentrate it much further; sphincteric resistance moderate (pig, sheep, goat, and cow).

4. *Gallbladder of high physiologic capacity,* having the power to concentrate a relatively concentrated hepatic bile six to ten times; sphincteric resistance high (duck, chicken, striped gopher, mouse, cat, dog, and *man*).

The above analysis, with its series of steps leading up to high sphincteric resistance in man, thus verifies the importance of clinical studies directly attacking the problem of biliary dyskinesia. Even more, however, it reveals the necessity of discriminating, experimentally, between the resistance offered by the duodenum and that produced by the intrinsic musculature that invests the terminal segment of the bile duct; for, if the choledochoduodenal junction of the species listed in Group 4 be examined histologically, it will be found that the extent to which the musculature of the duodenum envelopes the bile duct is much greater in the cat and dog, for instance, than in man;[2] and that this anatomic relationship undoubtedly retards the rate of emptying in animals—wit-

ness the studies of DuBois and Hunt on the opossum and cat.[3] Similarly it may explain why faradically induced spasms of the stomach and duodenum inhibit the flow of bile in the cat but not in man.[4]

On the other hand, the discharge of bile from the human gallbladder is speeded up by the presence of peptic ulcers[5] and markedly retarded by pregnancy.[6] In the latter instance, at least, the evidence is strong that retardation is due to a spasticity of the intrinsic musculature at the end of the common duct, and this view is strengthened by recent observations on the human fetus—where the disposition of muscle is easier to follow; namely, that the ampulla of Vater and its musculature is a retrograding segment[7] and that the most important part of the human sphincter of Oddi is the sphincter choledochus—a band of circular muscle enclosing the common duct just before the latter joins the pancreatic duct.[8]

It would thus seem that the time has come to emphasize both the functional unity of the extrahepatic biliary tract and its species peculiarities, and to recognize that in man, at least, a major rôle is played by the musculus proprius of the common bile duct.

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The Rôle of the Liver in Thyrotoxicosis

THE BELIEF has long been held that the liver is involved in the course of thyrotoxicosis. The most obvious evidence for such a view is the occasional development of jaundice during so-called thyroid crisis; more commonly, subclinical jaundice can be demonstrated by estimation of the icterus index during exacerbations, spontaneous or postoperative, of thyrotoxicosis. There is much similarity between the terminal stages of severe thyrotoxicosis and of hepatitis in that both are marked by fever, delirium, coma, and loss of vasomotor tone as shown by profuse diaphoresis and falling blood pressure. Findings at autopsy in patients who have died in thyroid crisis are notoriously meager, but focal necrosis appears in the liver and in the heart in so considerable a percentage of cases that it cannot be lightly dismissed. That more significance has not been attached to these pathologic findings is due to the fact that a less pronounced degree of parenchymatous damage, such as cloudy swelling, is

the anticipated event in most febrile forms of exitus. Again, the not infrequent occurrence of glycosuria in thyrotoxicosis is one of the expressions of impaired glucose tolerance. It has been generally considered to be due to an antagonism between the action of insulin and that of thyroxin; it is an established fact, however, that in diabetics decreased glucose tolerance as an expression of liver damage can be produced by a high fat diet alone and that the carbohydrate tolerance of diabetics is further impaired by the onset of thyrotoxicosis. Finally. the clinical value of high carbohydrate diet and, more dramatically, of glucose solutions given intravenously in severe exacerbations of thyrotoxicosis occurring spontaneously or postoperatively is quite as well established as in other conditions in which liver damage is proved.

More certain evidence of the rôle of the liver in thyrotoxicosis has waited, perforce, upon the development of a test sensitive to only moderate impairment of liver function. Such a test we now have, apparently, in Somogyi's method for quantitative determination of blood amylase.[1] With a margin of experimental error of not over 10 per cent, it is accurate for the estimation of small quantities of the enzyme, which cannot be claimed for other methods. It is the view of Somogyi and his coworkers, based upon several thousand determinations in the past five years, that the production of the enzyme depends upon the liver. It has now been shown that there is a relationship between the level of thyroid activity and the blood amylase.[2] These observations have been extended on more than one hundred patients. Feeding of thyroid substance to hypothyroid individuals lowers the blood amylase; it falls by as much as 50 per cent where thyroid medication is pushed to the point of toxicity. In untreated patients with thyrotoxicosis values, far below normal limits are common; clinical improvement after treatment and operation is accompanied by rise in blood amylase. The latter may lag considerably behind the other phenomena associated with restoration to normal thyroid status; indeed, some patients have developed postoperative myxedema at a time when the amylase has risen only to the lowest limits of normal range.

The behavior of blood amylase in the immediate postoperative phase is no less interesting. Serial observations show a large fall, usually within eight hours of thyroidectomy for toxic goiter; the low level is maintained for forty-eight hours, followed by a slow rise which may not have reached the preoperative level by the time the patient is discharged from the hospital. On the contrary, the enucleation of a nontoxic, solitary adenoma from an otherwise normal thyroid gland is not followed by alteration of the blood amylase.

This investigation was started in 1934 and the results as outlined above seem convincing to us as a conclusive indication of impaired liver function in thyrotoxicosis. While the assumption would be that all functions of the liver would be impaired, though not necessarily equally,

such speculation is fruitless until dependable methods for the estimation of serum lipase and the effectiveness of deaminization of amino-acids, to name but two indications of liver function, are available. Reports on the excretion of hippuric acid are conflicting and the method of Quick is still open to improvement. Extension and confirmation of this work will, we believe, not only throw new light on the nature of thyrotoxicosis but will prove of immediate practical value in the diagnosis of "borderline" or subclinical thyrotoxicosis and in the better control of thyroid medication.

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Recent Advances in Surgery

Conducted by Alfred Blalock, M.D.

CONGENITAL ARTERIOVENOUS ANASTOMOSES*

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I. INTRODUCTORY STATEMENT

ABNORMAL arteriovenous anastomoses are usually classified as congenital or acquired. The pathologic varieties are not to be confused with the normal communications between arteries and veins by means of which arterial blood passes from an artery to a vein without passing through a capillary bed. The existence of these latter "derivating channels" in nature has been recognized for many years. The former, or pathologic, varieties, recognized clinically because of the production of various signs and symptoms, while they are arteriovenous anastomoses, should more properly be referred to as arteriovenous fistulas. The so-called normal varieties are usually referred to as arteriovenous anastomoses. In this thesis arteriovenous fistulas will be characterized as AVF's, while arteriovenous anastomoses of the supposedly normal type will be referred to as AVA's.

The subject is one of many ramifications. This thesis is confined to a discussion of several of the relevant problems as follows: the historical background of arteriovenous anastomoses with a study of our knowledge of the genesis of the blood vessels; the anatomy, physiology, and pathology of arteriovenous anastomoses; a discussion of materials and methods used in studying blood vessels at Marquette University; and personal observations on laboratory material and clinical cases.

II. HISTORICAL BACKGROUND OF ARTERIOVENOUS ANASTOMOSES

A. *Genesis of the Blood Vessels.*—Since endothelium is the essential tissue of the vascular system, the question has naturally arisen as to the manner in which this endothelium makes its appearance in the course of ontogeny; also, where and when it arises in the embryo and how the endothelial-lined channels of the vascular system are established. According to McClure (1921, p. 219), two opposing theories have been advanced by European anatomists in answer to these questions: The angioblast theory of His, and the local origin theory. The advocates of vasculogenesis by invasion, Evans (1909, pp. 315-317), Bremer (1914, p. 464), and

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Minot (quoted by Jordan, 1930, pp. 192-193), regard the original angioblast, very early differentiated from mesenchyme, as the sole future source of endothelium, to which is ascribed a strict specificity throughout development. The advocates of the in situ method of origin, Huntington (1911, pp. 272-274), Miller (1912, pp. 489-490), Maximow and Schulte (quoted by Jordan, 1930, p. 193), on the contrary, conceive early vasculogenesis as a process of progressive fusion of tissue spaces and mesenchymal cells involving a continued differentiation of endothelium from mesenchyme.

The Angioblast Theory.—McClure (1921, p. 220) states that it has been observed in meroblastic ova, like those of the domestic fowl, that blood vessels and blood cells seem to make their first appearance on the yolk sac and then appear at a somewhat later stage of development in the body axis of the embryo. The early appearance of the blood vessels on the yolk sac led His (quoted by McClure, 1921, p. 220) to infer that certain cells on the yolk sac, which have been described by some as derivatives of entoderm and by others as derivatives of mesoderm, undergo an early differentiation to form a specialized tissue from which the endothelium of the yolk sac vessels and blood cells are exclusively derived.

This supposedly precociously developed vascular tissue formed on the yolk sac has been termed the angioblast by His (quoted by McClure, 1921, p. 220), who regarded it as forming a local unit vascular anlage from which, in addition to the endothelium of the blood vessels on the yolk sac, that which appears within the body of the embryo is also directly derived. According to the angioblast theory, the yolk sac angioblast grows into the embryonic axis from the yolk sac in a continuous and uninterrupted manner, thereby supplying to the embryo all of the material which subsequently gives rise to the endothelium of the entire intraembryonic vascular system. This theory that the yolk sac angioblast forms the unit vascular anlage of the entire vascular system precludes the possibility that the intraembryonic endothelium arises from any tissue in the embryonic axis other than the invading angioblast. The gradual and progressive manner in which the angioblast is supposed to grow into the embryonic axis also necessarily implies that no discontinuity between the angioblast on the yolk sac and any portion of that which has invaded the embryonic axis can possibly exist at any time or place. The angioblast, therefore, is regarded as being a highly specialized tissue, which is early differentiated during the embryonic development and which is at first confined to the area known as the yolk sac. That all intraembryonic endothelium is derived from this local unit vascular anlage by a process of continuous growth, and that this fact marks the specificity of the angioblast and its derivatives, is one of the primary and fundamental axioms of the angioblast theory. Another essential feature of the angioblast theory is that all intraembryonic

endothelium invariably arises from some preexisting endothelium. If it did not arise in this manner, it would have a local origin from some tissue other than endothelium.

The implied specificity of yolk sac angioblast, the origin from it of intraembryonic endothelium by a process of continuous growth, and the necessity thereby implied that all intraembryonic endothelium arises from some preexisting endothelium constitute the logical claims of the adherents of the angioblast theory.

The Local Origin Theory.—The view opposed to the angioblast theory is that of local origin. According to this view, mesenchyme may become vascular tissue in almost every region of the body. The cells which bound an intraembryonic blood vessel are not in direct lineage with those which line the early vessels on the yolk sac. They have not come into being as an ingrowth from the early yolk sac vessels or angioblast, and they have not necessarily come from preexisting endothelial cells, although some of them may have had such an origin, inasmuch as local origin does not preclude the possibility of growth during or following the process of local vascular formation. Addition to endothelium may take place (1) by proliferation of endothelial cells already formed; (2) by addition of single mesenchyme cells; (3) by addition of solid cell aggregates; (4) by addition of already formed endothelial cavities, the lining of cells of which have differentiated locally, in and from the mesenchyme; and (5) by the active migration and alignment of single mesenchyme cells to form vascular cavities. The local origin theory holds that blood cells are not necessarily descended from a primitive yolk sac angioblast, but that mesenchyme within the embryonic body is capable of giving rise to blood cells. Advocates of the local origin theory do not believe that the vascular anlage is necessarily differentiated at a very early stage of development, as claimed by His (quoted by McClure, 1921, p. 222),* or collectively and at one time, as stated by Minot (quoted by McClure, 1921, p. 222). Advocates of the mesenchymal theory recognize that there are certain regions in which a precocious production of vascular tissues takes place, but they claim that such regions are not the only regions in which such tissues are formed. Advocates of the local origin theory recognize various intraembryonic regions in which there is a first-hand production of vascular tissues, even relatively late in ontogeny, quite independent of such processes in the yolk sac. The angioblast theory regards endothelium as a tissue of high specialization quite foreign in nature to mesenchyme and quite removed from it genetically. The local origin theory claims that mesenchyme can transform into endothelium and that endothelium can change to mesenchyme.

McClure (1921, p. 223), in discussing the work of Florence Sabin on the development of the lymphatic system, states that in her early work

*With slight modifications this account of the local origin theory is taken from the papers of McClure (1921, p. 221) and Reagan (1917, pp. 39-130).

she believed that her results confirmed the angioblast or ingrowth theory of His. Viewed in this light, the endothelium of the lymphatics, like that of the blood vessels, would possess a marked specificity. It also could be traced back directly and continuously to a unit vascular anlage known as the angioblast. One theory favored by Sabin (1917, pp. 118-120) is that there is a limited period for the differentiation and growth of angioblasts out of undifferentiated mesenchyme and that after this period all new blood vessels arise from the growth or proliferation of older angioblasts. Another theory advanced by her is that angioblasts continue to differentiate out of mesenchyme indefinitely. If the former is correct, the problem is to determine which differentiate and which are formed from preceding vessels. McClure (1921, p. 232) reviews the history of research in this line. He discusses the papers of W. C. Clarke, Miller (1912, pp. 489-490), and McWhorter and Whipple (1912, pp. 121-127). Clarke (quoted by McClure, 1921, p. 232) showed that vascular endothelium, wherever encountered, hemal or lymphatic, may be an instance of the environmental adaptation of an originally isodiametric mesenchymal cell subjected to mechanical influence. From his analyses of the results of various investigations, McClure (1921 p. 235) believes that it is evident that the morphologic evidence favoring the general principle of a local origin of intraembryonic endothelium from mesenchyme has been completely confirmed by experiment, and accordingly that the angioblast theory, in the sense maintained by His, therefore, no longer holds. He believes that while differences of opinion may still exist, as regards details of the process, both for the lymphatic and blood vascular systems, it is plain that the general principle of the local genesis of intraembryonic endothelium from mesenchyme may now be regarded as an established fact.

Jordan (1930, p. 192) holds that the total evidence seems to favor the view that in earliest stages blood vessels may arise in the mesenchyme of the embryo and that these primitive stems may be added to by discrete anlages all of which may fuse to form the vascular net out of which develop the future main vessels. The vessels of later embryonic and fetal stages probably arise solely as sprouts from these earlier stems. He believes that the chief point of uncertainty concerns the point in time when vasculogenesis passes from a process including sprouting and fusion of separate anlages to one when extension occurs exclusively by terminal growth. Both arteries and veins have a like origin in capillary plexuses. The final anastomosing sprouts of endothelium represent the definitive capillaries. The development of the definitive wall of arteries and veins involves the formation of extraendothelial layers of muscular and connective tissue elements from the surrounding mesenchyme and also their association into the several tunics of the various subdivisions of these vessels.

Swindle (1935, pp. 7-9), in discussing his observations relative to the formation of arteriovenous connecting channels, states that as an em-

bryonic AVA grows in length, it loops away from its original position and divides into two or more parts wherever the surrounding tissue causes opposite walls of the anastomosis to come in contact with one another. Some observations made principally on viviparous snakes show that at the point of contact of the opposite walls these walls fuse to form two or more blood channels out of one and that the newly created vessels may separate widely from one another. Each of the new vessels may loop away in different directions and divide into two or more parts, and so on until the original anastomosis consists of a principal arterial trunk and a principal venous trunk which lie side by side and which are connected with one another at numerous points by relatively small arterial and venous branches and capillary networks. This metamorphosis may be of such a nature that the original AVA finally consists essentially of an arterial network, a venous network, numerous arteriocapillary anastomoses or terminal arterioles, numerous venocapillary anastomoses or terminal venules, and numerous capillaries.

In some tissues of the body, as in or near the cartilage of the pinna, some of the embryonic AVA's cannot loop away from their original positions. They are held in place by the solid tissues about them. These accordingly persist as relatively simple arteriovenous connections instead of very complex ones. Under certain conditions of congenital, partial obstruction of the flow of venous blood in a vein, embryonic AVA's fail to undergo metamorphosis at points somewhat centrally to the points of obstruction. Embryonic AVA's may accordingly persist in a tissue in which they are not ordinarily found. For instance, two persisting AVA's were found in the wall of the stomach of a human fetus, situated centrally to the point at which an artery is choking the vein. The metamorphosis of an AVA into an arterial and a venous trunk and their branches implies growth. It is important to observe in this connection that the growth and the resulting metamorphosis of the AVA's fail to occur at points where there is relatively little venous blood in the vein (due to venous obstruction) and a relatively large amount of arterial blood in this vessel (due to the inflow through the AVA or AVA's from the artery). Swindle (personal communication) has made the interesting observation that in the hearts of the Bovidae and Cervidae arterial anastomoses, connecting the longer arteries, are present. These disappear during development to the adult form, and the remaining arteries are then end arteries in the sense of Cohnheim.

B. *The Anatomy of the Capillaries.*—It is generally accepted that the normal means of communication between arteries and veins is through a capillary bed. In studying AVA's, which may be considered either as abnormal structures or as representing an arrangement which is different from that usually considered as normal, it is well to review briefly our knowledge of the capillary bed. The anatomic literature is disappointing in its report of the number, distribution, and surface of the capillaries. Gray's *Anatomy* (1907, p. 584) merely states that the capil-

laries vary from $\frac{1}{3,000}$ to $\frac{1}{2,000}$ of an inch in diameter and from $\frac{1}{20}$ to $\frac{1}{30}$ of an inch in length, while Cunningham (1931, p. 872) states that the average diameter of the capillaries varies from 8μ to 12.5μ and that the average length is 0.75 mm. Krogh (1929, p. 24) states that the capillaries have practically never been counted, and means are wanting in the reports of much of the work which has been done to ascertain the size of the structures which have been graphically depicted. In most tissues the arrangement of the capillaries is so complicated that the difficulties in the way of even approximate measurements are very formidable. The capillaries in a given field often vary considerably in diameter. They sometimes may be so narrow that they cannot admit red corpuscles even when these are greatly compressed. On the other hand, in the human skin the diameter may be as large as 0.02 mm. (Krogh, 1929, p. 34). Mall (quoted by Krogh, 1929) describes the average diameter of the capillaries in the intestinal villi as 8μ to 5μ. On other areas of the intestine they are of about the same diameter, and from 0.4 to 0.2 mm. in length. In injected specimens of the intestinal villi, Krogh (1929, p. 40) found them to be of an average diameter of 12μ. Vimtrup (quoted by Krogh, 1929) states that the average diameter of capillaries in the kidney glomeruli is 10μ and the average length is 0.5 mm.

Krogh (1929, p. 29) gives the number of capillaries per square millimeter as $1,350 \pm 31$ in the gastrocnemius of the horse. The transverse section of an ordinary pin is 0.5 mm. It requires some mental effort to conceive how there can be room within such a pin for about 700 parallel tubes carrying blood, in addition to about 200 muscle fibers. In other animals he states that the number of capillaries per millimeter may be even greater. There seems to be some relation between the number of capillaries and the metabolic activity. In the dog's semimembranosus muscle there are $2,630 \pm 51$ per square millimeter. In the smallest mammals there may be as many as 4,000 per square millimeter. In cold-blooded animals, such as the cod and frog, there may be about 400 per square millimeter. Krogh (1929, p. 29) states that there should be a study of the quantitative anatomy of muscle capillaries.

In human skin, according to Krogh (1929, p. 34), on the dorsum of the hand there are 64 capillaries per square millimeter. In the forearm, 47; cheek, 16; and in the circumoral skin, 20. It is a characteristic feature of the blood vessels of the human skin that there is no very sharp distinction between the smallest arterioles ("capillary arteries"), the capillaries proper, and the venules ("capillary veins"). The venules in the outer part of the cutis are so thin walled and present such a large total surface that they have practically taken over the normal function of capillaries.

Capillaries in the rete mirabile annexed to the oxygen gland in the eel are 4 mm. long (Krogh, 1929, p. 34). The organ is 8 sq. mm. across.

The capillary surface is venous, 106 sq. mm.; arterial, 105 sq. mm. The volume of the capillaries is venous, 25 c.c.; and arterial, 18 c.c. The desirability of extending our knowledge of the anatomy of the capillaries is obvious, and Krogh, in his excellent monograph on the *Anatomy and Physiology of the Capillaries,* makes a plea for their study from the standpoint of quantitative anatomy.

Brown (1925, p. 57), of the Mayo Clinic, states that in studying the form and behavior of capillaries it is exceedingly difficult, in certain instances, to determine where the normal leaves off and the pathologic begins. In many apparently normal persons occasional loops are short and tortuous, dilated or contracted, or are otherwise abnormal. The granular appearance of the flow or the cessation of flow, and plasma gaps may also be observed in single loops. Brown thinks that in the normal person, however, these are isolated phenomena. Not until the majority of the loops are abnormal in form and flow are the capillaries classified as pathologic. When a sufficient number of capillaries reveal stasis with dilatation, a definitely recognized cyanosis will exist; and when a sufficient number are empty or only partially filled, pallor of the skin will be recognized macroscopically. Ebbecke (quoted by Brown, 1925) has shown that the degree of dilatation of the capillaries and venules determines the color of the skin, while arterial dilatation determines the heat of the skin. In differentiating the pathologic from the normal, the quantitative changes, rather than the qualitative, indicate disease. Abnormal capillaries, in the absence of clinical manifestations, occasionally are encountered.

That the capillaries have an independent contractility seems reasonable. These vessels exhibit responses perhaps more delicate than those of the larger vessels. This would be expected on the basis of structure and function. According to Krogh (1929), anatomic researches have demonstrated contractile or Rouget cells with fine fibrillae wrapped about the endothelial tube. The transitional point from arteriole to capillary, or from capillary to venule, is not always well defined in the vessels of the skin. In lower orders and certain capillaries of mammals the transitional point is definite.

The studies of Brown (1925, pp. 59-62), of the Mayo Clinic, have shown that the capillary undergoes involutionary changes with advancing age, probably similar to those observed in the larger vessels. The capillary apparently becomes longer; the calibers are narrowed; and the increased length may manifest itself as a long, straight, or tortuous loop. According to Brown, the usual normal type in the young adult is the hairpin shape, fairly regular and uniform, but there are variations. Occasionally young persons have uniformly thick, tortuous loops. The absence of narrowed lumina seems to differentiate these from the pathologic tortuous types. The greatest difficulty in distinguishing diseased capillaries arises in cases in which the normal and abnormal types are

present in about equal numbers. At best, one observes occasional cases in which no conclusion can be drawn relative to capillary morphology. In Brown's studies the average total length of the visible capillary loop in the normal group was 0.42 mm. The average caliber of the arterial limb was 0.007 mm.; and of the venous limb, 0.009 mm. These are the averages of a group of 110 approximately normal persons from the ages of twenty to ninety-five years. The normality of these persons was based on the absence of demonstrable disease and normal cardiorenal vascular findings for their age.

Cowdry (1934, p. 102) comments on the fact that the capillaries may not only be absent and their place taken by AVA's, but it is also possible that contrary to the general rule, they may not form a closed system of vessels in the spleen. Kyes (1901, pp. 37-43) stresses "the lack of demonstrable continuity of vascular connection between the ultimate capillaries of the arterial and venous systems." It remains to be discovered whether in this locality the endothelial walls are continuous or whether they exhibit openings which allow the blood cells to escape into the surrounding tissue. Maximow and Bloom (1930, pp. 399-400) claim that the transitional vessels are not lined with endothelium but by expanded reticular tissue, and that the manner in which blood passes from arterial capillaries into venous sinuses is not known. If this contention is proved to be correct, this is the second locality in which the blood stream is not limited by the walls of endothelium, the first being the circulating maternal blood in the placenta which is confined to spaces lined with tissue of ectodermal origin.

C. *The Anatomy, Physiology, and Pathology of Arteriovenous Anastomoses.*—

Anatomy.—According to Krogh (1929, p. 100), in the anatomic literature of fifty years ago there are a number of references to the existence of "derivating channels," represented by small arteries opening directly into somewhat larger veins. Much of this early evidence for the presence of such direct connections was based upon the appearance in the vein of suspension of granules, injected into arteries, the consistence of which was presumably too large to enter capillaries. With the work of Hoyer (quoted by Krogh, 1929, pp. 100-106), the presence of AVA's in various regions of different animals was demonstrated conclusively by a number of different staining and injection methods. Hoyer found such anastomoses in the ear of the rabbit, cat, and dog, and in the tip of the nose, in the lips, toes, the tip of the tail, and the cavernous tissue of the sexual organs of most mammals. In man he was able to demonstrate them only in the hand and foot (especially in the fingers and toes) and in the sexual organs. Histologically, Hoyer described connections from artery to vein as pursuing a straight course, or, more frequently, a winding one. Their wall he found to be thick and muscular on the arterial side and thin walled at the funnel-shaped venous portion. Hoyer (quoted by

Krogh, 1929, pp. 100-106) made a search for these "derivating channels" in many other places, but, apart from the case of the arteries opening directly into the corpora cavernosa, he found them only in such projecting parts as might require a considerable supply of blood to keep them warm when exposed to low temperatures.

Following Hoyer, several other investigators have studied AVA's histologically. Among these Krogh (1929, pp. 100-106) mentions especially Grosser, who confirmed Hoyer's results and who gave excellent descriptions of the finer structure of such direct connections in the toes of various mammals, including man. Grosser found them to be numerous in the skin of human fingers where they are arranged in small groups, 1 to 2 mm. apart. Their musculature is twice to thrice as strong as that of arteries of the same bore (about 0.02 mm.), and they are imbedded in connective tissue with numerous nuclei. They are common, also, within the digital bones where they are surrounded by a venous plexus which allows them to open and close freely. They are especially large (0.1 to 0.2 mm.) in the thumb of bats. Grosser has made a search for them in appropriate places in reptiles where they appear to be absent. Swindle (personal communication) stated that in numerous injections in bats he has been unable to confirm the presence of AVA's in this animal.

In the last few years evidence has been brought forward for the existence of AVA's from intravitam observations of the circulation in the human skin. Heimberger (quoted by Krogh, 1929, p. 102) has been able to observe such connections directly and in considerable numbers in the fingers of persons having a very delicate skin. He describes them as short connections between peripheral arterioles and venules, short circuiting the long capillary loops. He finds these channels, normally closed, to be opened up for a short period by weak mechanical stimulation. Krogh states that he should not attach much weight to these observations, which must be exceedingly difficult to verify, but for the two facts that Heimberger is an observer of quite extraordinary ability and patience, and that his direct findings are supported by observations of the blood flow in superficial venules and capillaries which are explicable only if AVA's exist in close proximity to the vessels under observation. In a few cases Heimberger reported seeing pulsation of the blood in venules when the corresponding arterioles were closed and the blood in the capillaries quiescent. As Krogh points out, this is possible only when the venule in question possesses another connection with the arterial system, through which the pulse is admitted. In other cases the blood is seen for some time to flow back from a venule through the capillaries to an arteriole, which postulates that the venule is connected directly with a somewhat larger artery, transmitting sufficient pressure to carry the blood back into an arteriole which must also be in direct communication with a larger vein.

Krogh concludes that it follows from the observations of Heimberger that his "derivating channels" which are distal to those of Hoyer and Grosser must be able to contract and expand and to close up entirely.

Grant (1930, pp. 282-283) found anastomoses in all parts of the rabbit's ear. He states that they are most numerous on the dorsal surface of the thinner portion and are situated in the deeper layer of the skin and on the surface of the underlying perichondrium. On three portions of perichondrium from the dorsal aspect of the ears of three rabbits, two portions measuring 13 by 8 mm., and one, 12 by 9 mm., no less than 65, 53, and 46 separate communicating channels were counted by him; that is to say, about 1 to 1 or 2 sq. mm. in the average. They are mostly tortuous vessels, arranged in groups, uniting neighboring arteries and veins. Less commonly they form short lateral communications between parallel vessels or an artery may approach a vein and open directly into it. They vary in size, the internal diameter of the arterial side measured in optical section being from 20 to 70μ. This agrees with the diameter of the column of blood flowing through them when maximally dilated during life. The arterial is narrower than the venous end, the difference being slight when the vessel is dilated; when the arterial side is constricted, the channel is funnel shaped. Grant (1930, p. 283) states that structurally the anastomoses fall into three sections. On the arterial and on the venous sides they have the usual structure of these vessels, though the wall of the arterial portion is thicker than in arteries of a corresponding lumen, the adventitia being stouter and the muscle cells more numerous. The third section, the region of transition, Grant states, is not so simple as Hoyer depicts it; it is more accurately represented by Grosser's description of anastomoses in human skin. In this region the adventitial and muscular thickening is greatest; the muscle nuclei are shorter and rounder and are not arranged so regularly around the vessel. The numerous nuclei in the sphincter-like thickening give the anastomoses a dark color rendering them conspicuous. The adventitial thickening is continued, decreasing for a short distance on the expanding venous end though the muscle cells cease or become sparse rather abruptly.

Clark and Clark (1934, p. 281) viewed living AVA's in the rabbit's ear through special chambers introduced by operation. They found that AVA's were visible in all chambers immediately after the operation. In stable chambers they numbered from 25 to 55 in the observation area of 1.6 sq. cm., being more numerous in rabbits with an active circulation. Followed over a period of months, they were found to be relatively permanent structures, fully as persistent as arterioles and far more so than venules and capillaries.

According to these workers, the arrangement of AVA's was found to be varied. The majority arose from smaller arteries, but a certain number arose from larger arteries; others, from arterioles; others formed the

termination of an artery; and clusters of three or more from the same artery were frequently seen. The veins into which a number of AVA's emptied were usually large, while occasionally they had a fairly thick muscular wall and showed definite contractility.

Clark and Clark (1934, p. 282) state that the two forms of AVA's described by Hoyer, straight and coiled, were seen by them in the living preparations. In studies extending over weeks or months, the lengthening of certain AVA's, due to stretching, and the bending of others, apparently due to slight compression, were observed. The division into three parts, the arterial, the narrow thick-walled intermediary portion, and the thin-walled, funnel-shaped venous portion, was also seen in the living AVA's and, as a rule, the intermediary portion showed the most active contractions, while the funnel did not contract. Although typical, this form is not the only one, however, as AVA's were observed in which the muscular wall extended from artery to vein with little differentiation in form or contractility. Variations in size (diameter or lumen) of living AVA's were marked in different AVA's in the same area and in the same one on different days, while the diameter of a single AVA frequently changed several times per minute, according to the degree of dilatation or contraction.

From their studies, Clark and Clark (1934, p. 239) found that anastomoses, in addition to being normally present in large numbers in the rabbit's ear, are relatively permanent. That new anastomoses occasionally formed in the chamber areas seemed certain, although here again care was necessary in order to be sure that a supposedly new anastomosis was not merely a preformed one which had remained closed for some time and then reopened. In several chambers, however, the appearance of a new anastomosis was observed in a region which had been submitted to extensive study, part of the time with higher microscopic magnification, for months. Despite the formation of occasional new ones, the apparent loss of a few others and the undoubted changes of formation of many individual anastomoses observed, a cross-connection between a given artery and vein once located could be identified, in the majority of cases, at the same site over a period of months. Anastomoses appeared to be fully as stable in form and position as the smaller arteries and larger veins, and conspicuously more so than the venules and capillaries which have been shown to be remarkably labile.

Their observations on the distribution of anastomoses in the human skin are summarized in the following table by Grant and Bland (1931, p. 393). Anastomoses are absent from dorsum of fingers, toes, hand, and foot; from flexor surface of lower forearm and lower calf of leg, and from lower half of ear.

The authors Grant and Bland (1931, p. 392) state that the anastomoses are especially conspicuous by reason of their thick walls with

TABLE I

NUMBER OF ANASTOMOSES PER 1 CM. SURFACE AREA

Hand	
Index finger	
Nail bed	501
Tip	236
Palm, 3rd phalanx	150
Palm, 2nd phalanx	20
Palm, 1st phalanx	93
Palm	
Metacarpophalangeal joint. 3rd finger	31
Thenar eminence	113
Hypothenar eminence	96
Foot	
2nd toe	
Nail bed	593
Pad	293
Sole—near heel	197

numerous rounded nuclei. In appearance they are not unlike the ducts of the sweat glands. They found the anastomoses to be arranged chiefly in groups situated at the level of, or a little superficial to, the sweat glands. They are thus much too deeply placed to be seen from the skin surface during life. They are mostly tortuous channels and open into a rich network of thin-walled veins. Their lumina in their preparations varied from 20 to 70μ, the average being 35μ. Grant noted that the diameter of the anastomoses in preparations of the rabbit's ear made by this method agreed well with their diameters measured when maximally dilated during life. Grant and Bland (1931, p. 393) also injected a full-term stillborn fetus, but they found no anastomoses in places where they found them in adult skin. In this connection they noted that Grosser and others failed to find anastomoses in newborn or fetal material.

Krogh (1929, p. 106) states that in a very recent publication Wearn (1928) demonstrates the existence of anastomoses in the heart of man and other mammals between the coronary artery and the Thebesian veins. These latter vessels normally drain off a considerable portion of the venous blood from the heart muscles directly into the right and left ventricles. The anastomoses with the artery are opened up when the heart, which has ceased beating, is dilated by injection. Their function during normal life is entirely unknown, but Wearn mentions two human cases where it was found at autopsy that the orifice of the coronary artery was entirely occluded and that the heart muscle could receive its blood supply only through these anastomoses. The occlusion had developed slowly but was of long standing, and the supply through the Thebesian anastomoses had enabled the patients to lead a normal working life.

A peculiar anomaly, an arteriovenous communication between the right coronary artery and the coronary sinus with aneurysmal dilatation of the parts involved, is described by Halpert (1930). The condi-

tion was an incidental finding at necropsy in a patient, adult man (aged fifty-four years), who died of carcinoma of the stomach and who presented during life no clinical evidence suggesting a cardiac defect.

Grossly abnormal arteriovenous communications have been recognized for many years. Reid (1925, *b*, p. 996) states that both Antyllus and Albucasis accurately noted the physical signs of a condition we now recognize as arteriovenous aneurysm, although they did not recognize its cause and, therefore, could not give to it the name of arteriovenous aneurysm. According to Reid, the condition of abnormal arteriovenous communications was first accurately described by William Hunter in 1757. Callander, in 1920, collected 447 cases of all kinds, 3 being congenital. Reid, in 1925 (1925, *a*), reported 33 cases of abnormal arteriovenous communications. Twenty-seven were acquired and 6 congenital. Lewis, in 1930, collected 33 cases in the literature (congenital). These include the cases of Reid and 3 from the Mayo Clinic. Horton, in 1931, reported 24 cases from the Mayo Clinic between the years 1929 and 1931, and in 1934 he reported 38 cases seen up to that time. In only one case was the diagnosis made before entrance to the Clinic. In 19 cases reported by Lewis, surgical exploration was carried out. This was followed by amputation in 11 cases, and surgical cure was obtained in only 1 case. The report of 1 case is here added.

Physiology.—Grant (1930, p. 281), from his observations on direct communications between arteries and veins in the rabbit's ear, concludes that we have no conception of the function of AVA's based on experiments. Flushing of the ears is dependent on the temperature to which a rabbit's body is exposed, rather than that to which the ear is exposed. He (Grant, 1930, pp. 283-300), found that the anastomoses in the rabbit's ear react to mechanical stimulation, histamine, acetylcholine and cold, by dilatation, and to adrenaline by contraction. They can be dilated by the local axone reflex, and they are particularly responsive to sympathetic impulses, contracting vigorously. Stimulation of the sympathetic with faradic current, he found, causes contraction. An unusually rich distribution of the perivascular nerve plexus to the AVA's is described. The anastomoses, according to Grant (1930), serve two functions: (1) local—it is mainly through their agency that the temperature of the ears is maintained when these are exposed to cold; (2) general; they are important factors in regulating body temperature, aiding in the dispersal of heat by allowing an enormous blood flow through the ears. Grant and Bland (1931) confirm these observations. They found numerous anastomoses present in the bird's foot and found that the foot responds to cooling by a vigorous temperature reaction. In man many anastomoses are found in the palm of the hand and sole of the foot and they are particularly numerous at the ends of the digits. These parts also react strongly when cooled, and they state there are reasons for believing that the anastomoses not only take part in the

vascular reaction but are the vessels chiefly responsible for the increased blood flow. Grant and Bland (1931) point out that the presence of anastomoses in the skin is not essential to the development of the temperature reaction; for example, although they are apparently absent from the lobe of the human ear, yet the lobe usually reacts vigorously when cooled. They think it may be that the hand and foot, exposed at the end of long limbs and often in contact with cold surfaces, require a special vascular arrangement, which is not needed in the ear, adequately to protect them against cold; or it may be that the anastomoses in the hand and foot, while playing an important part in the reaction to cold, are restricted chiefly to these regions for some special and unknown reason. From their limited distribution, it seems to these authors that they are little more than a minor factor in the regulation of body temperature in man in whose relatively hairless body other mechanisms are more effective for this purpose. That they serve different functions in different parts of the body seems to them likely. Of some of their functions there is evidence, namely, maintenance of the temperature of exposed parts and regulation of loss of heat. It has been suggested, first by Muller (quoted by Grant and Bland, 1931), that anastomoses are responsible, at least in part, for erection of the penis. Of other functions we are as yet ignorant and even speculation fails to suggest a purpose for the AVA's in the human glomus coccygeum. Grant and Bland note the anatomic relationship between AVA's and Pacinian corpuscles which they state were described by Grosser and Schumacher. They emphasize that the activity of AVA's under various conditions, such as have been described, and their presence in large numbers in certain parts of the animal body, should be borne in mind in a variety of circumstances. For example, they introduce a disturbing element into the interpretation of changes in capillary pressure measured at the base of the finger nail and because of their presence, pressure changes observed here during hyperemia cannot be taken as representing those occurring in other regions where anastomoses are wanting. Again, their ready response to various stimuli should not be neglected in experiments on the blood flow through the limbs of cats and dogs, especially in relation to the action of drugs. Further, since they have been described by previous workers as present in a number of animals, not only in the ears, nose, and feet, but also, among other places, in the pia mater of the brain, in the capsule and parenchyma of kidney, and in the corpus cavernosum of the penis, the authors believe, that they must be taken into account in dealing with the circulation in these and other parts of the body. In this connection, however, Grant and Bland (1931) believe it is to be emphasized that many of the older statements as to the presence or absence of anastomoses throughout the body require confirmation. Thus, for example, while they found numerous and large communications between the arteries and veins on the perichondrium at the

tip of the rabbit's ear, they failed to discover in two rabbit and two dog kidneys and one human kidney anastomoses such as, they stated, have been described by Geberg and Golubew. It seems clear that many more anatomic and physiologic data require to be collected on these interesting direct communications between arteries and veins.

Grant and Bland (1931, p. 306) summarize their conclusions as follows:

1. Numerous AVA's are present in the foot of the domestic hen and duck.

2. The foot of these birds responds to cooling by a vigorous temperature reaction closely resembling that of the human finger.

3. In man many anastomoses are present in the sole of the foot and palm of the hand and they are particularly numerous at the ends of the digits.

4. These are the parts that also react strongly to cold, the reaction being best displayed where anastomoses are most numerous.

5. Though other parts of the body yield a temperature reaction in the absence of AVA's, the authors believe that in the extremities the anastomoses not only take part in this vascular reaction but are chiefly responsible for the increased blood flow.

6. Because of their activity under various conditions and their presence in large numbers in certain parts of the animal body, AVA's require to be taken into account in dealing with the peripheral circulation.

Clark and Clark (1934, pp. 282-284), in their studies of living AVA's in the rabbit's ear, found that those AVA's most exposed during the operation remained dilated and noncontractile for hours or days, while the deeper ones, like the arterioles, usually remained narrow or closed. Subsequently, the dilated AVA's narrowed or closed completely for a period, while the others widened. Spontaneous periodic contractions of most of the AVA's in the chamber returned within two days to a week after the operation, although an injured AVA or portion thereof might remain dilated and paralyzed for a longer period. The difference in recovery rates was probably due to varying degrees of nerve injury.

AVA's in stable chambers were seen by Clark and Clark (1934) to contract and dilate spontaneously, each at a rhythm which was usually independent of that of the artery from which it arose or from that of other AVA's in its immediate vicinity. The behavior of individual AVA's frequently varied from day to day, even with surrounding conditions as nearly uniform as possible. The active opening and closing of AVA's had a marked effect on the direction, speed, and volume of blood flow in the veins into which they emptied.

Mild stimulation (tactile) of the rabbits caused the AVA's to contract with the arteries. Sudden noises also caused contraction of the AVA's with the arteries, although an exception on the part of one AVA was noticed on one occasion. In sleep, with arteries all dilated and

sluggish circulation, many of the AVA's also widened, while others contracted tightly, and still others continued to open and close rhythmically.

Clark and Clark (1934, p. 283) state that, in general, AVA's, like arteries, were wider at warmer and narrower at cooler temperatures, although with moderate changes in either direction the contraction rhythm was maintained. Usually, local heating of the ear had to be as high as 40° C. before many AVA's ceased rhythmic contractions and remained dilated, although the arteries usually showed lengthening of the dilatation period at 32° C. to 36° C. However, some AVA's always continued to contract with no change in rate or length of the dilated period at temperatures of 40° C. to 44° C., while a few in each chamber failed to respond in any perceptible way to heating. Similar exceptions were noted with moderate degrees of cooling when most of the AVA's, like the arterioles, stayed narrow. An AVA which responded to heating or cooling in any one way on a certain day might behave quite differently on the next day. Within the moderate ranges of temperature used, a wide variety of individual reaction was always noted whenever a number of AVA's were kept under prolonged observation. AVA's located near regions of local infection, like the arteries, remained persistently wider than the normal vessels. In such cases the spontaneous contractions of the AVA's usually ceased before those of the neighboring arteries. However, Clark and Clark (1934, p. 284) observed an exceptional AVA, located near such an infected spot, which failed to widen and which continued to contract rhythmically. They found that stimulation caused contraction; while in sleep, some opened, some contracted.

In general, AVA's dilated with warmth and contracted with cold. The behavior to local heat and cold might vary from day to day. In areas of local infection they remain widely open.

In concluding their observations, Clark and Clark (1934, p. 281) state that perhaps the most striking characteristic of the living AVA's as shown by their study is their erratic behavior. General pictures of their usual activity can be given and general statements made concerning their reactions to change of temperature, to sleep, and to infection, but individual exceptions must be made in all of these cases. It would, therefore, seem inadvisable to base conclusions as to the behavior of AVA's in general upon observations of the reaction of a few of them on any one day.

Starling (1933, p. 1015), in discussing the physiology of AVA's, states that the blood flow through the skin is under the control of the central nervous system through the vasoconstrictor and vasodilator nerves, and when the skin is cooled it is by altering the size of the cutaneous vessels that the central nervous system chiefly acts in regulating heat loss. In cold weather or when heat production in the body is low, the vessels are constricted, the skin is cold, and the heat loss is small. In the extremities of the body, excessive skin cooling, with ensuing tissue damage, is

probably prevented by the opening up of the AVA's. In this way the skin surface is flushed with warm blood so that its cooling is delayed. The anastomoses are controlled, probably centrally, by constriction or dilatation of the arterioles.

Pathology.—In clinical medicine the existence of abnormal arteriovenous communications is recognizable by the presence of certain rather obvious symptoms and signs. The most common sites for the occurrence of AVF's are the head (scalp and intracranial), the neck, and the extremities. The relative rarity of these lesions in the trunk is of interest in view of Halpert's (1930) description of a congenital AVA in the heart and of Swindle's (1935, p. 3) finding of a congenital AVA in the walls of the fetal stomach. The changes produced by the presence of AVF's are usually grouped under the local, the regional, and the general or systemic. The local clinical picture as well as the nomenclature may be confusing. As Lewis (1930, p. 4) points out, it is frequently impossible to differentiate between various vascular lesions, for they may have several common characteristics. They are classified in diverse fashions by different authors. Reid (1925, *b*) believes that there is no essential difference between arteriovenous aneurysms, cirsoid aneurysms (racemose aneurysms), arterial Ranken-angiomas or aneurysms by anastomosis, pulsating angiomas, and possibly simple angiomas. Reid believes that all are probably instances of abnormal arteriovenous communications, and, therefore, that the term arteriovenous aneurysm is all embracing. As he states, the medical profession has come to regard arteriovenous aneurysms as having to do with trunk line vessels and not with the very small arteries and veins. For instance, the condition that results when a blow on the head establishes a free communication between the vessels of the scalp is known as a cirsoid aneurysm and not as an arteriovenous aneurysm. Matas (quoted by Reid) defined an arteriovenous aneurysm as any abnormal communication established between the arterial and venous channels. The terms hemangiectatic hypertrophy and congenital phlebarteriectasis have also been used to describe this condition.

According to Lewis (1930, p. 3), the arterial Rankenangioma (racemose or cirsoid arterial aneurysm) has been defined as a vascular tumor in which all the arteries of a region, including their finest branches, often communicating with each other, are dilated and tortuous. Secondarily, the veins, according to most authors, are involved. Wagner (quoted by Lewis, 1930) believes that the formation of new vessels is characteristic of an angioma of this type, that the newly formed vessels have a decided tendency to growth, and that there is an eccentric hypertrophy of the vessels of small caliber already existing. The arterial racemose aneurysm has been differentiated from lesions known as diffuse phlebarteriectasis and diffuse phlebectasis. Diffuse phlebarteriectasis is supposed to be characterized by a progressive dilatation of an arterial bed

with its capillaries and veins, while in diffuse phlebectasis only the veins are involved in the dilatation. It would seem that the terms AVF and arteriovenous aneurysm are used rather indiscriminately. The fact that AVA's exist in what may be considered the normal state of many animals and the fact that clinicians recognize only the very obvious alterations produced by relatively large communications raise the question as to the existence of border line or unrecognizable AVA's. The term "arteriovenous fistula," in Horton's (1931) paper, is used to designate any abnormal communication or communications between arteries and veins by means of which arterial blood passes from an artery to a vein without passing through a capillary bed. It includes the various direct and indirect communications described in literature as cirsoid aneurysm, arteriovenous aneurysm, pulsating venous aneurysm, arteriovenous varix, aneurysm by anastomosis, angioma cavernosum, angioma arteriale racemosum, aneurysm serpentina, and angioma arteriale.

Horton (1931, p. 665) states that he agrees with Dandy (1928, p. 192) that the various terms, "cavernosus," "racemose," "cirsoid," and "serpentine," whether applied to arteries or veins, are merely descriptive of a superficial expression of a lesion and not of the fundamental pathologic process. The terms, he says, for the most part are useless and serve only to confuse the reader. The fundamental pathologic process is the same regardless of whether the arteriovenous fistula is in the foot or in the cranial cavity. Intracranial AVF's offer the best opportunity for a study of the gross appearance of the abnormal arteriovenous connections. Dandy (1928) observed that since the veins are free from all accessory coverings it is possible to see through the walls of the veins and detect the pulsing red arterial blood against a background of black venous blood. Cushing and Bailey (1928, p. 54), while exploring the great vessels of the neck in a well-advanced case of AVF (angioma arteriale), observed that the internal jugular vein was markedly enlarged and that "it looked much lighter in color than normal, and on inspection, though the vein was not definitely pulsating, one could see what appeared to be a current of arterial blood passing down in the venous stream." Horton (1931, p. 666) states that if one could only visualize the regional vessels and the abnormal arteriovenous communications in the extremities of the group of cases reported in his paper he believes that one would see the same pictures which have been so accurately described by Dandy and Cushing. He thinks this is amply indicated by the oxygen studies which were carried out. In each case there was a high admixture of arterial and venous blood in the regional or deep veins of the involved extremity. The bright red appearance of the blood in most cases was sufficient to warrant the diagnosis of an AVF.

Pemberton and Saint (1927, p. 791), in reviewing the effects of abnormal arteriovenous communications, describe the symptoms and signs. The usual effects may be considered from three aspects: the local, the

regional, and the general or systemic. The local effects, they state, are those manifested by the affected blood vessels. The blood from the artery flows into the distal part of the vein, greatly increasing the volume of blood in it and producing a pressure greater than the vein is normally capable of withstanding. As a result, the vein becomes dilated and tortuous. Similar changes take place, though probably not to such a great extent, in the proximal part of the vein. The larger the fistula and the longer its duration, the more widespread will be the venous involvement, in many cases almost all the veins of a limb which is the site of a fistula being affected. Reid (1920) found in experiments on dogs that there was an increase in the elastic tissue in the walls of an involved vein (the so-called arterialization). Pemberton and Saint (1927) were able to examine microscopically the veins in the vicinity of the anastomosis on one case only and found no evidence of arterialization, but calcareous degeneration was well marked in the internal part of the middle coat in one section.

The effect of an AVF on the involved artery, according to these authors, consists of dilatation, thinning of its walls, and degenerative changes in its coats, all of these changes taking place, in greater or less degree, only proximal to the fistula. Holman (1924, p. 816) has drawn attention to the fact that when the cross-section of the fistula is small these changes may be hardly noticeable or even entirely absent, although the fistula may have existed for many years; whereas, when the fistula is large, they are invariably present, particularly the dilatation and thinning, in marked degree. As to the cause of these changes in the proximal artery, opinions are somewhat divided. According to Pemberton and Saint (1927, p. 792), some authors believe that the diminished blood pressure causes loss of tone and functional inertia which results in the changes just described. The objection to this theory is that the diminished blood pressure is general and, since other arteries are not affected, it would seem that the cause is local rather than general. Others take the view that the increased amount of blood flowing through the artery is sufficient to account for them. Reid (1920, pp. 43-50) thinks that it would be unusual if a simple handling of an increased volume of blood by the proximal vessels did not lead to an hypertrophy and strengthening of their walls. While it is true that dilatation, thinning, and degeneration of the walls of the hollow viscera are often the sequelae of previous hypertrophy, yet this is not always so, and Pemberton and Saint (1927, p. 793) offer another explanation of these changes. In the first place, the dilatation is acute. In support of this are the observations that it is present only when the fistula is large and that it occurs almost at once after the production of the lesion. Second, the dilatation causes constriction of the vasa vasorum, and this results in diminished nutrition of the vessel wall, leading finally to thinning and degeneration.

The regional effects are those evident in the particular limb affected. The first is hypertrophy, as seen in the increased girth and, at times, increased length of the limb. The latter indicates an overgrowth of the bones and is found only when the lesion has been established for some time before the ossification of the epiphyseal cartilage, so that congenital cases are particularly liable to show it. The second effect is increase in superficial temperature, and the third, trophic changes. Pemberton and Saint (1927, p. 793) believe that the first two can be explained by the increased volume of blood flowing through the limb consequent upon the production of the fistula. They account for the trophic changes as being produced by two factors: First, the diminution of the flow of blood through the capillaries owing to its easier path of escape into the veins through the fistula, and second, the increased pressure on the veins impeding the return of deoxygenated blood from the capillaries. These two factors working together tend to bring about a state of anoxemia of the tissues affecting more particularly those most distally situated. On this account, if these tissues become even slightly injured, the normal inflammatory reaction necessary for their repair is either feeble or absent, and hence chronic progressive ulceration (partial obstruction) and later gangrene (total destruction) supervene. In their series in Cases 3, 5, 6, and 8, that is, all those in which an extremity was affected, chronic ulceration and gangrene were quite prominent features.

Bruits and thrills are found over the affected area in some cases. In 23 cases reported in 1932, Horton (1932, pp. 6, 7) found bruits present in 8 of the 23 cases, and thrills in 4 of these 8. By perfusing the arterial tree with water under a pressure of approximately 150 mm. of mercury in the amputated extremity in Case 1, Horton states that the bruit and thrill were reproduced and could be distinctly heard and felt in the region of the wrist. The arterial tree was injected with a mixture of sodium bromide and gelatin, and roentgenograms of the injected extremity were made. This illustrated abnormal communications between the arteries and veins. There were also some small communications in the bone itself. These observations were confirmed by dissection of the arm. There were also some small aneurysms in the arteries and veins similar to those previously described by Wilbur (1930).

The cause of the overgrowth of extremities, particularly the cause of the increase in length, is a subject of great interest. Horton (1934, pp. 460, 461) states that the increased flow of blood is the cause of the hypertrophy both of the bone and of the soft tissues. He states, also, that arteriograms of several subjects, the length of whose bones in the involved extremities had increased, revealed that the AVF's were adjacent to the epiphyseal line; whereas, arteriograms of three subjects without such increased length of bone in the involved extremities revealed that the abnormal communications between the arteries and veins were along

the shaft of the long bones. Horton believes that the increased length occurs when abnormal communications have existed for a considerable time before ossification.

Dry and Horton (1935, p. 661), in describing a case of spontaneous closure of a traumatic AVF involving the right femoral artery and vein, stated that "despite the fact that the fistulous communication was in the upper part of the thigh, the increase in bony growth was in the tibia rather than in the femur." Pemberton and Saint (1927, p. 793) also explain hypertrophy and increase in length of extremities as being due to an increased volume of blood flowing through the limb. On the other hand, they explain the trophic changes sometimes observed as due to the diminution of blood flow through the capillaries and the increase in pressure on the veins thus impeding the return of deoxygenated blood from the capillaries. These two factors, they believe, tend to bring about a state of anoxemia of the tissues affecting more particularly those most distally situated. Starling (1933, p. 1015) states that through the opening of the AVA's in the rabbit's ear the skin is flushed with warm blood so that its cooling is delayed. As Swindle (personal communication) has pointed out, the presence of AVA's or of abnormal fistulas has a tendency to shunt the blood directly into the veins and in that way to produce a decreased rather than an increased blood flow.

In the description of an arm which had been amputated because of changes resulting from AVF's, Pemberton and Saint (1927, p. 784) noted that upon injecting a solution opaque to Roentgen rays the solution returned almost immediately through the cut ends of the vessels. The solution filled the dilated proximal arteries and veins, the more distal vessels being only partially filled, because of the short circuiting due to fistulous communications. The stimulation of bone growth by venous stasis has been observed for many years. According to Pearse and Morton (1930), Ambroise Pare utilized stasis hyperaemia in order to stimulate the formation of callus. They state that later Nicoladoni advocated this method of treatment for the same purpose. In their survey of the literature on the effect of venous stasis upon bone growth, Pearse and Morton note that several observers have recorded clinical improvement in the repair of bone in the presence of venous stasis and that various authors have shown that any long continued inflammatory process which results in venous congestion will be followed by increase in the length and thickness of the bones. This response follows such causative factors as irritation of the periosteum, the introduction of foreign bodies, or the presence of a chronic ulcer of the leg in a young person. Pearse and Morton (1930) also state that the venous congestion resulting from arteriovenous aneurysms, angiectasis, and varicose veins may all produce a hyperplasia of bone. The passive congestion resulting from cardiac failure and the congestion of arteriosclerotic extremities

may result in a hyperplasia of bone growth, according to Cone (quoted by Pearse and Morton). Studies on the blood changes in venous stasis made by Peters, Bulger, Eisenman, and Lee (1926) revealed an increase in the volume of the formed elements and increase in total plasma protein and an elevation of oxygen capacity and carbon dioxide content. The pH was reduced and relative acidity prevailed. The total acid and base of the plasma remained relatively constant while the salt content was apparently unchanged. Swindle (1935, p. 11) is of the opinion that the reduction of pH may be the factor which stimulates growth.

Harris and Wright (1930, pp. 142, 143) studied a case of hemangiectatic hypertrophy of the limb and made observations upon the rate of growth in the presence of increased blood supply in kittens who had been subjected to sympathectomy. These authors reported the case of a boy aged ten years with an overgrowth of the right leg. The right femur was 1 cm. longer than the left, while the right leg was 4.5 cm. longer than the left, most of the overgrowth of the extremity occurring below the knee. From the description given, it would seem that abnormal arteriovenous communications existed above the level of the knee. The authors assumed that there was an increase in the blood supply as a result of the AVF's. It would seem that the same conditions prevailed in this case as in other cases of abnormal venous communications with hypertrophy and that there was a venous stasis responsible for the overgrowth rather than an increase in blood supply. Cannon and others (1929) found that sympathectomy causes no change in the growth of long bones as compared with the normal side in kittens four months old. Harris and Wright (1930, pp. 147, 148), as a result of their experiments, also came to the conclusion that destruction of the sympathetic innervation of the forelimb of kittens with its resulting increased blood supply results in no increase in its bony structure.

The general or systemic effects depend on the disturbance in the function of the circulatory system produced by the development of the fistula and also on nature's efforts at compensation. Normally the circulatory system consists of heart, arteries, capillary bed, and veins. The formation of an AVF creates a new path through which the blood can flow, a second system, consisting of heart, artery, fistula, and vein being thus formed. The essential point of difference between the two systems is that the second (fistulous) system is practically devoid of peripheral resistance. Since a fluid will always flow along the path of least resistance, the less the peripheral resistance of the fistulous system, the greater will be the tendency for blood to pass through it. In order that blood may still continue to flow through the capillary system with its high peripheral resistance, it is essential that an adequate general blood pressure should be maintained (Holman, 1924, pp. 802, 803).

The systemic effects may be considered from three aspects: (1) peripheral resistance and blood pressure; (2) total volume of circulating blood; and (3) the reaction of the heart (Pemberton and Saint, 1927, p. 794).

While systolic pressure is chiefly maintained by cardiac output, diastolic pressure, on the other hand, is largely maintained by the elastic recoil of the arteries against the peripheral resistance. Following the production of a fistula the peripheral resistance is much diminished. Thus in AVF one would expect a normal or nearly normal systolic pressure and a low diastolic pressure, with consequent increase in pulse pressure. These are usually found, particularly in cases of the traumatic type. In 9 congenital cases reported by Pemberton and Saint, a low diastolic pressure was noted only in 3. On closure of the fistula (and, therefore, reestablishment of the normal peripheral resistance), the diastolic pressure rises to normal, while the systolic pressure usually remains about the same, although there may be a transient rise. Hoover and Beams (1924) reported that on closure of a fistula the systolic pressure rose by the same amount as the diastolic, but in most of the reported traumatic cases the systolic, as already mentioned, remains the same or rises only a few points. Owing to the multiple anastomoses present in congenital cases, these changes in blood pressure are difficult or impossible to elicit because of the difficulty of closing all of the fistulas simultaneously. Horton (1935, p. 460) states that the blood pressure was invariably higher on the involved side in cases of congenital AVF's.

Holman (1924, p. 802) has pointed out that because of the easier path of escape offered to the blood from the arterial system by an AVF, the amount of blood passing through the system, heart, arteries, capillaries, and veins is reduced according to the size of the fistula; that in order that the supply of blood through this system will be sufficient for the needs of the body, an adequate general blood pressure must be maintained; and that one of the compensatory mechanisms to insure this is an increase in the total volume of the circulating blood. He proved his theory to his complete satisfaction by experiments on dogs in which he had produced AVF's, showing that when the lesion was small (and, therefore, the amount of blood short-circuited back to the heart was correspondingly small) the blood volume remained constant or nearly so, while with larger fistulas he found a definitely increased blood volume together with changes in the heart and proximal vessels. Even admitting that the present methods for the determination of blood volume leave much to be desired, his results seem definite enough to be outside the limits of experimental error.

From a comprehensive study of blood volume (by the dye method of Keith, Rountree, and Geraghty) in health and disease, Brown and Rowntree (quoted by Pemberton and Saint, 1927) do not regard the results obtained by present methods of estimation as absolute, but be-

lieve that for comparative work they are reliable. They have found that blood volume between 70 and 100 c.c. for each kilogram of body weight may be regarded as normal for different healthy individuals. On the other hand, the blood volume in the same healthy individual estimated at different times under comparable resting conditions may vary as much as 5 c.c. for each kilogram of body weight after ligation of the main arteries involved, a decrease greater than the normal variation. This single piece of clinical evidence, although supporting Holman's (1924) experimental results, does not justify any definite conclusions being drawn. However, these authors hope in due course to have the opportunity of studying blood volume in a sufficient number of cases to be able to satisfy themselves as to whether the data in this single case can be satisfactorily corroborated or not.

In many of the cases reported in the recent literature on the subject, enlargement of the heart has been noted, some times accompanied by symptoms or signs of myocardial degeneration (Pemberton and Saint, 1927). Until comparatively recently, it was thought that the heart condition was coincidental and that, if the state of the heart were poor, the surgical risk was correspondingly great and operation contraindicated. During the war, however, observers had the opportunity of studying a large number of cases, and they began to recognize that the condition of the heart was not coincident with, but consequent on, the production of the fistula. One of the most striking cases is reported by Leriche (1919). This surgeon extirpated an arteriovenous aneurysm in a case in which considerable cardiac enlargement and general signs of cardiac decompensation were present. The heart returned to its normal size and the signs of decompensation disappeared. This case, together with later abundant experimental work and clinical investigation by the Americans, Holman (1923), Reid (1925), Hoover and Beams (1924), and the Englishmen, Lewis and Drury (1923), has completely proved the detrimental effect of abnormal arteriovenous communications upon the heart. Opinions differ as to the cause of the cardiac enlargement. Lewis and Drury (1923) maintain that it is largely due to dilatation consequent upon faulty nutrition of the myocardium, the low diastolic pressure being insufficient to permit of adequate filling of the coronary vessels. On the other hand, Holman (1924), in experiments on dogs, found that in addition to dilatation there was an increase in the weight of the heart which he concluded must be due to hypertrophy. In Pemberton and Saint's series, cardiac enlargement was only demonstrable in two cases. It did not occur in any of Reid's (1925, *a*) cases.

An AVF has been described as analogous to an aortic leak, but, whereas in aortic regurgitation the left side of the heart alone undergoes dilatation and hypertrophy as a compensatory measure, in AVF both sides of the heart undergo these changes, the right side on account of having to cope with the increased intake consequent upon the abnormal

escape of blood into the veins through the fistula, the left side in order to increase output to maintain adequate general blood pressure. If Holman's contention be correct, in addition to these factors, the heart has to deal also with increased total volume of blood.

Lewis (1930, p. 18) states that while Branham is given credit for noting that in closure of an AVF slowing of the pulse rate is produced, and this observation has since been spoken of as Branham's bradycardiac phenomenon, this sign was described by Nicoladoni fifteen years before it was noted by Branham. He states that, however, Nicoladoni did not describe the lesion as a congenital arteriovenous aneurysm. It could not be elicited in any of the congenital cases in Pemberton and Saint's (1927, p. 796) series because of the difficulty in closing the multiple communications.

III. MATERIALS AND METHODS USED IN THIS INVESTIGATION

An intensive study was made of a clinical case presenting features of congenital AVF's. Clinical studies included x-ray examination, arteriography, infra-red photography, skin surface temperatures, careful measurements, and studies of the oxygen content of the blood in the affected and sound sides. Laboratory studies of various injected tissues were made. These tissues were prepared and injected by Dr. P. F. Swindle, India ink and cinnabar suspension being used. The injected tissues were cleared by the Spalteholz method and in some instances decalcification with HCL was employed. The tissues were examined with the binocular microscope. Among the tissues studied were the following: human liver and gallbladder; foot of a swan; penis of prong-horned antelope and Scotch buck; stomach of human fetus; turbinate of reindeer; ears of the rabbit, timber wolf, kangaroo, coyote, dog, and antelope; capsule of the dog's kidney.

The Spalteholz method consists of dehydration of the tissues with absolute alcohol, displacing the alcohol with benzine, the benzine then being displaced with synthetic oil of wintergreen. The arteries were injected first with India ink and then with red cinnabar suspension. By this method the ink is driven into some of the capillaries only or into the capillary venules and veins. If the cinnabar is not firmly packed into the arteries, some of the ink may remain in some of the smallest arteries. The amount of ink passing into and beyond the capillaries may depend upon the amount of ink injected as well as upon the amount of cinnabar packed in the arteries. Under certain conditions, an abundance of cinnabar can be urged through the capillaries and into the veins. According to Swindle, this can be accomplished best by first diminishing the elasticity of the perivascular tissue while the intravascular fluid pressure is being altered in a rhythmic fashion. The pulsatile variations in the vessels may be produced while the tissue is placed for several seconds in a moderately concentrated

HCL and then for an hour or more in tap water. A more convenient method consists of injecting a 2 per cent or 3 per cent solution of HCL into the arteries and varying the injection pressure for many minutes. The tissue becomes edematous and loses its elasticity to such an extent that if a portion of it is compressed with a blunt object, such as a finger, this portion remains deformed for some time. Likewise, when the perivascular tissue is repeatedly forced aside by the walls of the rhythmically dilating vessels, it remains compressed for a sufficient length of time so that the veins, as well as the arteries, can be packed with cinnabar by injecting this substance in a rhythmic manner into the arteries. If no AVA's are present, cinnabar or India ink may be driven from the arteries into the capillaries, but not entirely through them into the veins, or the injected substance may be urged into the veins through the capillaries. Cinnabar can rarely be packed firmly enough in the capillaries for these vessels to be visible in photomicrographs. Very slender columns of India ink in the lumen of the capillaries can be demonstrated much better photographically than the slender columns of cinnabar in the lumina of these vessels.

IV. DIRECT OBSERVATIONS

A. *Injected Blood Vessels.*—In the laboratory studies of injected blood vessels, AVA's were found in the ears of the rabbit, timber wolf, coyote, kangaroo, and dog (see Figs. 1 and 2); the stomach of the human fetus (Swindle, 1935); the tunica albuginea of the prong-horned antelope; and the Scotch buck (Dysach, unpublished material). No AVA's were found in the mucous linings of the nasal passages of any of the mammals examined; in the human liver or gallbladder or in the capsule of the dog's kidney. They were not found in the injected specimen of the swan's foot, but this preparation was not entirely satisfactory so that our failure to demonstrate them in this tissue cannot be interpreted as meaning that they did not occur. AVA's were found in these tissues in a number of varieties. Funnel shapes were frequent in the rabbit's ear, but not so common in the other tissues. In the ear of a dog whose body had been cooled with ice water before death, there was marked contraction of the AVA's (Fig. 2) as compared with those found in the ear of another dog whose death occurred at normal room temperature (Fig. 1).

B. *Clinical Observations.*—

CASE 1.—The patient, a white male, aged nine years and five months, was admitted to the Milwaukee Children's Hospital on March 18, 1935, because of swelling of the right leg. Two and one-half years before admission he had injured the right leg when he jumped off a stump. Following this accident, the right ankle was swollen and painful. The father assumed that the ankle was sprained. The swelling diminished very slowly, and the ankle never returned to normal size. Since the accident the ankle has become larger during the day when he is active and the

swelling has subsided somewhat at night. For several months following the accident, the ankle ached considerably. He has been wearing a high boot in order to prevent the swelling during the day and finds that this has been of some benefit to him. The veins of the right leg have been observed to be somewhat larger than those of the left leg. No swelling was noticed prior to the accident.

The patient's general health has always been good. Aside from draining ears at various times during the past six years, his past history for acute diseases is essentially negative. At the age of nine years he was in grade 3-B, and the father thinks his mental development is average. The father is well. The mother died in

Fig. 1.—Photomicrographs showing typical AVA's in dog's ear. India ink was injected into the carotid artery and this was driven over into the capillaries, AVA's, and veins by injecting cinnabar suspension into the same artery. The magnification of the large photograph is 103.9 and of the insert, 27. Reflected light only was used in making these pictures. *A*, artery; *V*, vein; *AVA*, arteriovenous anastomosis.

1927 following an abortion. There are three living children in the family, aged twelve, nine, and eight years. The other two children are well.

The patient is a thin, fairly well-developed boy. He is round shouldered and assumes a fatigue posture. The abdomen is prominent. He walks without a limp. He is alert and cooperative. Aside from the presence of a perforation in Shrapnell's membrane on the right, examination of the head and neck is essentially negative. The chest is symmetrical except for the suggestion of a pigeon breast. His heart is within normal limits, the apex being in the fifth interspace, 1 cm. within the mid-

clavicular line. There is a faint systolic bruit at the apex which is not transmitted. There is no thrill present. The rate is normal. Except for its prominence, the abdomen is negative. The right lower leg is larger than the left. There is some edema about the right ankle. The superficial veins are prominent on the right and become markedly engorged on standing. The entire right lower extremity becomes slightly dusky in color when the patient is erect. The upper extremities are equal in size. The superficial arteries of the arms and legs are palpable and apparently equal bilaterally. No thrills or bruits are present over the arms or legs. The skin temperature of the right leg is grossly higher than that of the left. Detailed studies

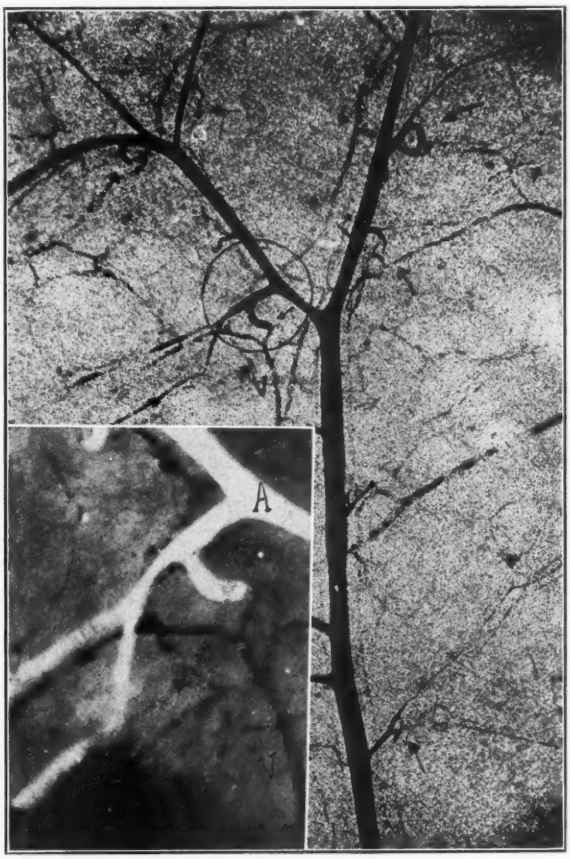

Fig. 2.—Photomicrographs showing typical AVA's in dog's ear. The method of injection is the same as that used for Fig. 1. This animal's body had been exposed to ice cold water immediately before death. The insert represents the area within the circle of the large photograph. The magnification of the large photograph is 27.6, that of the insert is 69. Reflected light only was used in photographing the insert, while the large photograph was made with reflected and transmitted light. Note the exaggerated contraction of the AVA's in this figure in comparison with those shown in Fig. 1.

of skin temperature readings are given in following tabulations. Routine examinations of the blood and of the urine were essentially negative. The blood pressure was as follows: right arm, 110/60; left arm, 105/60; right leg, 130/80; left leg, 120/80.

On March 18, 1935, 10 c.c. thorium dioxide solution (thorotrast) was injected into the right femoral artery with compression of the artery above the site of in-

jection. X-rays were taken immediately. It was found that the solution had escaped into the veins within 30 seconds and the arteries could not be satisfactorily visualized.*

Studies of venous blood taken from the right popliteal area and from the left arm showed that the blood in the right popliteal area was much brighter red in color than was the blood from the arm, and its oxygen content was increased 12 per cent. Infra-red photography† revealed very strikingly the marked difference in the

Fig. 3.—Infra-red photograph of boy with congenital arteriovenous fistulas involving the right leg. The marked difference between the veins of the right and left legs is strikingly demonstrated by this method.

venous dilatation of the two sides and revealed venous channels which could not be seen by the naked eye (Figs. 3 and 4). Electrocardiographic studies showed no abnormalities of the heart and an x-ray picture of the heart made at 2 M. showed it to be of average size and of usual configuration.

*Articles on arteriography by the following authors will be found in the bibliography: Alexander et al. 1934; Allen and Camp, 1935; Horton and Ghormley, 1935*a*, *b*; Paris correspondence, 1935*a*, *b*, *c*; Veal and McFetridge, 1935.

†Articles on infra-red photography will be found in the bibliography under the following author: Massopust, 1935*a*, *b*.

The patient was under observation in the out-patient department until July 11, 1935, when he returned for the purpose of having another injection of thorium dioxide into the right femoral artery in an effort to visualize fistulas between the arteries and veins. On July 17, 1935, 18 c.c. of thorium dioxide solution (thorotrast) was injected into the right femoral artery, compression being made above the artery during the injection. Pictures made within 30 seconds, during which time the artery was compressed, showed that practically all of the solution had entered the veins and no fistulas could be demonstrated. On August 19, 1935, the femoral

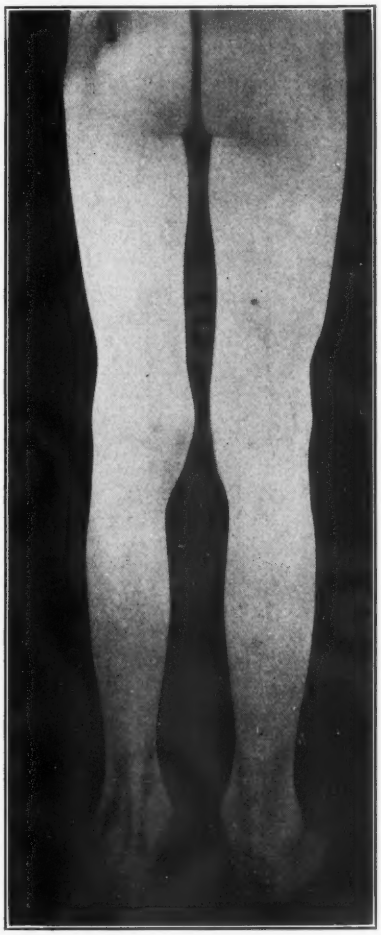

Fig. 4.—Photograph of a boy with congenital arteriovenous fistulas of right leg (same patient as shown in Fig. 3), taken with ordinary light. It is difficult to see the veins of the right leg. They were somewhat more prominent on physical examination, but their extent was not apparent.

artery and vein were exposed throughout their course by surgical operation. The femoral artery and vein appeared normal except at one point where a small branch of the vein was greatly dilated. This was just proximal to the opening in the adductor magnus. The artery profunda femoris was traced downward to the point where it perforated the muscle to go to the back of the leg. Below the second perforating branches there was considerable enlargement and tortuosity of the accompanying vein. A branch of the profunda femoris appeared to enter into this mass.

The vein was bifurcated at this point. The artery profunda femoris was ligated below the second perforating branches. This produced marked diminution in the size of the vein.

There was little change in the local condition following this operation, and on October 7, 1935, the popliteal artery and vein were exposed and thoroughly examined. No communicating fistulas were found. There were numerous small branches coming off of both the artery and vein. These were ligated and cut.

The boy's recovery following both surgical procedures was uneventful and while he remained in bed there was considerable diminution in the size of the leg, but the induration in the soft parts below the knee did not entirely disappear. The x-ray showed definite thickening of the soft parts of the right leg and thigh. There were many dilated veins visible on the calf of the right leg, especially on the lateral aspect.

The skin surface temperatures and the measurements of the lower extremities taken at various times are as shown in Table I.

TABLE I.

March 18, 1935; Temperature	*Right*	*Left*
Arm	34.8° C.	34.4° C.
Forearm	34.6° C.	24.2° C.
Thigh	35.4° C.	34.6° C.
Calf	35.0° C.	34.6° C.
Gluteal fold	36.2° C.	35.0° C.
Popliteal space	34.6° C.	34.6° C.
Foot	33.4° C.	32.4° C.

Measurements	*Right*	*Left*
Circumference 24 cm. above thigh	36.5 cm.	34.2 cm.
Circumference 17 cm. below knee, calf	26.6 cm.	23.5 cm.
Circumference ankle	24.6 cm.	23.0 cm.
Circumference arm	17.0 cm.	16.8 cm.
Circumference forearm	17.5 cm.	17.2 cm.
Length anterior superior spine to internal malleolus	75.5 cm.	75.5 cm.
Length knee to internal malleolus	36.6 cm.	36.6 cm.

Measurements	*3-14-35*	*4-25-35*	*7-11-35*	*9-9-35*	*9-24-35*	*10-31-35*	*11-26-35*
Right ankle	7.6 cm.		20.0 cm.	18.5 cm.	20.0 cm.	20.5 cm.	20.5 cm.
Right calf	26.8 cm.	28.0 cm.	27.0 cm.	26.0 cm.	27.0 cm.	26.0 cm.	28.0 cm.
Right knee	30.8 cm.		31.0 cm.	31.6 cm.	32.5 cm.	34.0 cm.	38.0 cm.
Right thigh	34.0 cm.	36.2 cm.	34.0 cm.	34.5 cm.	36.5 cm.	34.0 cm.	38.0 cm.
Left ankle	7.6 cm.		17.0 cm.	17.0 cm.	17.0 cm.	16.5 cm.	17.0 cm.
Left calf	24.0 cm.	25.0 cm.	24.0 cm.	23.0 cm.	24.0 cm.	23.5 cm.	25.0 cm.
Left knee	29.2 cm.		29.5 cm.	29.5 cm.	30.5 cm.	29.5 cm.	30.5 cm.
Left thigh	30.3 cm.	33.1 cm.	31.5 cm.	33.0 cm.	34.0 cm.	33.0 cm.	35.5 cm.

Temperatures	*8-10-35*		*9-9-35*		*9-24-35*		*11-7-35*	
	Right	Left	Right	Left	Right	Left	Right	Left
Arm	35.0°	34.0°	35.2°	35.2°	35.0°	35.2°	35.4°	35.5°
Forearm	35.2°	35.0°	35.2°	35.4°	36.6°	36.0°	35.3°	35.4°
Hand	35.4°	35.0°	35.4°	35.4°	36.0°	35.8°	35.8°	35.6°
Thoracic	34.8°	35.0°	35.4°	35.2°	35.8°	36.0°	35.4°	35.0°
Lumbar	34.6°	35.0°	34.6°	34.6°	36.2°	36.2°	35.0°	34.4°

Temperatures	*8-10-35*		*9-9-35*		*9-24-35*		*11-7-35*	
	Right	Left	Right	Left	Right	Left	Right	Left
Thigh:								
Anterior			35.4°	35.2°	35.8°	35.0°	36.0°	35.8°
Posterior	35.2°	35.0°	35.0°	35.0°	36.2°	36.0°	34.4°	34.0°
Calf	36.0°	34.4°	34.2°	34.0°	36.4°	35.6°	34.2°	32.0°
Popliteal	35.0°	34.6°	35.4°	35.0°	36.4°	36.2°	34.3°	33.6°
Gluteal	35.6°	36.0°	37.0°	36.0°	37.2°	36.2°	35.9°	35.4°
Patellar			36.6°	33.6°	36.6°	35.2°	36.2°	35.4°

CASE 2.—A white female, aged eight years, was seen in consultation with Dr. Walter P. Blount on January 20, 1936. This child complained of a small left leg. The discrepancy in size of the left leg was noticed by the child's father, who is a physician, when the child was six weeks old. No history of injury or of contagious disease could be elicited. Recently the discrepancy between the right and left legs had become more noticeable. There was no history of pain in the extremities. Examination of the pelvis and both lower extremities was negative except for the increase in length of the bones of the right leg. The measurements are shown in Table II.

Fig. 5.—Infra-red photograph of child with hemihypertrophy involving the right leg. The absence of abnormalities of the veins of either leg is well demonstrated by this method and is of definite value in eliminating the presence of arteriovenous fistulas.

The right foot was at least 1 cm. different in length from its fellow. When standing on a ¾-inch elevation under the left foot, the pelvis was level and symmetrical. Standing in bare feet, there was a left total scoliosis. The left arm hung away from the side, while the right hung next to the body. There was moderate pronation of both feet, which was not excessive. There was no difference in temperature of the legs on palpation, except over the knee where the right was warmer. X-ray pictures, anteriorposterior of the lower extremities, revealed no

TABLE II

	RIGHT	LEFT
Forearm	20.6 cm.	20.4 cm.
Upper arm	22.6 cm.	21.3 cm.
Length of arm from the acromion to the radial styloid	44.0 cm.	44.0 cm.
Circumference of calf (standing)	35.0 cm.	30.8 cm.
Circumference of thigh (standing) 15 cm. above the patella	48.5 cm.	44.2 cm.
Length of leg	74.2 cm.	71.0 cm.
Circumference of calf with legs elevated	34.2 cm.	30.5 cm.
Circumference of thigh (relaxed) 15 cm. above the patella	48.0 cm.	43.5 cm.
Length of tibia	32.0 cm.	31.0 cm.
Length of femur (measured obliquely)	42.0 cm.	41.0 cm.

difference in the conformation of the long bones, which in the right were larger in every way than the left: right tibia, 32.5 cm.; right femur, 41.5 cm.; left tibia, 31.5 cm.; and left femur, 39.0 cm. The ischiopubic synchondrosis on the right was enlarged and not completely closed. That on the left was completely closed. Otherwise the epiphyses on the two sides were symmetrical and the bones were negative for radiologic changes.

This child was examined by means of infra-red photography which revealed no dilatation of the deep veins (Fig. 5). This method was of assistance in eliminating the presence of abnormal communications between the arteries and veins in this case. The final diagnosis of hemiphypertrophy of the right leg was decided upon because of the absence of any abnormality of either leg other than the difference in size.

V. GENERAL DISCUSSION

The relative rarity of congenital AVF's in clinical medicine is noteworthy in view of the development of the blood vessel system. The origin of the arteries, veins, and capillaries from a common bed not only explains the occurrence of these fistulous communications, but makes their infrequent occurrence worthy of comment. As Sabin (1917, p. 120) has noted, in certain embryonic vessels the direction of the flow of blood may be reversed so that these vessels which function as arteries during one stage of development, function as veins during another. Woolard's (1922) plates show clearly the capillary network through which the forelimb bud of the pig embryo first gets its blood supply, and how, at a later period, when subclavian artery and vein are beginning to be differentiated, there are numerous communications between the two vessels. Reid (1925, *b*) expresses wonder at the fact that pathologic varieties of AVA's do not occur more frequently. Swindle's (1935, p. 8) observation that some embryonic AVA's are fixed by solid tissue about them so that they cannot loop away and develop normally is worthy of considerable thought. It has some clinical support in the fact that Lewis (1930) reported a case of congenital AVF's involving the ear, and that several cases have been reported in which large arteriovenous communicating channels have occurred in bone. It is probable that since our attention has been directed to this subject by the work of Halsted (1919), Reid (1925), Pemberton and Saint (1927), and Horton (1931), more

cases will be recognized. The relative increase in the number of cases seen at the Mayo Clinic within a few years would tend to substantiate this statement.

The method of development of the blood vascular system is of interest, not only as providing an academic background for an understanding of this subject, but also because it helps to throw some light on the nature of the processes sometimes seen in clinical medicine. The essential similarity between various types of blood vessel tumors and AVF's has been commented upon previously in this thesis. Reid's (1925, *b*) statement that there is a basic similarity between cirsoid aneurysms and arteriovenous aneurysms is particularly interesting. Trauma is a common factor in both and he believes that angiomas, cirsoid aneurysms, and arteriovenous aneurysms have the same etiologic basis. Trauma was an important factor in the history of the case presented here and is noted in many clinical reports. Lewis (1930) states that trauma is by far the most frequent cause of arteriovenous aneurysms, and the history of injury in many of the cases in the literature seems to be more than coincidental. It is probable that some anomaly in the blood vascular anlage permits the development of this lesion, when some causative factor, such as trauma, may result in spontaneous communications between the arteries and veins. Horton and Ghormley's (1935, p. 141) observation of the appearance of an arteriovenous communication in the leg following obliteration of a congenital fistula in the thigh is also of interest in this regard, as it illustrates the probable existence of a preformed channel which had not become clinically apparent. Clark and Clark's (1934, p. 239) observation that new AVA's appeared in a region which had been submitted to extensive study for many months is also significant in considering the clinical aspects of these cases. In applying our knowledge of the genesis of the blood vessels to this subject, one is safe in assuming that the preponderance of evidence favors the principle of the local origin of intraembryonic endothelium from mesenchyme. McClure, in his address as President of the American Association of Anatomists in 1924, stated that the angioblast theory as proclaimed by His no longer holds and voiced his belief that the theory of local genesis of endothelium is an established fact. This statement was especially significant in view of the controversy which had raged for years in the American Association and among European anatomists regarding this subject. McClure's views have not been challenged in the literature since that time and they undoubtedly represent the conclusions of the anatomic world today.

The disappointing lack of accurate knowledge of the anatomy of the capillaries is evidenced by the meager reference made to these structures in standard textbooks on anatomy and the lack of special works on this subject. The monograph of Krogh (1929) stands almost alone in the academic field, while Brown (1926, 1929, 1935), of the Mayo Clinic,

working in clinical medicine, has made, in recent years, important contributions to our knowledge of these structures both in normal and abnormal subjects. It is evident from the studies of these two men that there is a great variation in the capillaries so that an approach to this subject, with a view of determining the effect of pathologic communications, is hampered by a lack of accurate knowledge of the normal. The possibility that the blood may not be limited by walls of endothelium in some regions, as for instance in the spleen, further complicates the picture.

The existence of AVA's is generally accepted. These derivating channels are not to be confused with the pathologic AVF's of gross anatomy. Krogh's (1929, p. 103) statement that, though wider than arteries when fully dilated, AVA's are much too small to be seen with the naked eyes and cannot in any way imperil the circulation even when present in very large numbers, is significant in view of the inadequate state of our knowledge regarding the anatomy and physiology of these structures. Clark and Clark (1934, p. 281), from their studies, conclude that without question the changes of blood flow and the oxygen content of the venous blood from regions in which these structures are numerous must be greatly modified. The lack of clearly defined limits between what may be considered normal and what is to be considered pathologic when arteriovenous communications occur independent of a capillary bed is at once apparent. The earlier work of Hoyer (1877) has been confirmed in part by Grant (1930), Grant and Bland (1931), Clark and Clark (1934), and Swindle (1935). The observations here recorded also tend to confirm some of the earlier reported work. However, the opinion of Swindle (personal communication) that one cannot accept too freely earlier statements relative to the existence of AVA's, and his emphasis on the necessity of studying further their distribution must be kept in mind before any conclusions are accepted. Grant and Bland (1931, p. 406) also voice the opinion that much of the earlier work on AVA's needs confirmation. In this connection it should be noted that in the literature it is stated as an accepted fact that AVA's are present in the corpora cavernosa. Swindle and Dysach (personal communication) have not been able to confirm the presence of AVA's in the corpora cavernosa of several animals examined, but they have found numerous AVA's in the tunica albuginea in the prong-horned antelope and Scotch buck.

The evidence relating to the function of AVA's is conflicting and it would seem that thought regarding these structures is somewhat confused. While AVA's are usually credited with increasing the blood flow to a part, a consideration of the anatomic arrangement would lead one to believe that in some instances a decrease in the amount of blood flowing through a region might occur because of the short-circuiting effect of these structures. The wide variation in the reaction to various stimuli is well demonstrated by the works of Grant (1930) and of Clark and

Clark (1934). A perusal of the literature merely emphasizes Grant's (1930, p. 280) statement that we have no experimental evidence of the function of AVA's.

In considering the regional changes produced by the pathologic varieties of arteriovenous communications, the cause of the overgrowth of extremities is especially interesting. It is obvious that there is no unanimity of opinion regarding the basic nature of the process responsible for this phenomenon. In all of the cases described, increase in length occurred only when abnormal communications existed for a considerable time before ossification. Clinicians generally dismiss the subject by the statement that the increase in length is due to an increase in the local blood supply. Tending to prove this point, Horton (1934, p. 461) has reported on arteriograms of several subjects, the length of whose bones in the involved extremities had increased, revealing that the AVF's were adjacent to the epiphyseal line. In three subjects without such increase in length of bone in the involved extremities, the abnormal communications were along the shafts of the bones. Dry and Horton (1935) describe a case of spontaneous closure of a traumatic AVF involving a right femoral artery and vein and state that "despite the fact that the fistulous communication was in the upper part of the thigh, the increase in bony growth was in the tibia rather than in the femur." Pemberton and Saint (1927, p. 793) also explain hypertrophy and increase in length of extremities as being due to an increased volume of blood flowing through the limb. On the other hand, they explain the trophic changes sometimes observed as due to the diminution of blood flow through the capillaries and the increase in pressure on the veins, thus impeding the return of deoxygenated blood from the capillaries. It is probable that rather than being due to an increase in blood supply, overgrowth is due to passive hyperemia and to the presence in the extremity of relatively deoxygenated venous blood. The references to the stimulation of bone growth by venous stasis previously referred to, and which is well recognized clinically, would tend to confirm this point. Further confirmation is found in the work of Cannon and others (1929), in which an increase in the blood supply to the extremities of kittens following sympathectomy did not result in an increase in growth of the long bones. In the case reported by Harris and Wright (1930), the increase in the length of the leg occurred mainly below the point of the AVF's. Here the authors also assumed that the increase in length was due to an increase in blood supply; whereas, venous congestion would seem to be a more reasonable interpretation. That the increase in length and the hypertrophy of the tissues are due to a change in the blood supply rather than some other factor is supported by physiologic thought. Claude Bernard (quoted by Cowdry, 1928, vol. 1, p. 3), called the interstitial lymph, in which cells are immersed, the *milieu intérieure*. This great physiologist believed that the metabolic condition of the cells de-

pended on the composition of this medium. Alexis Carrel (quoted by Cowdry, 1928, vol. 1, p. 3) states that the quantitative and qualitative reactions of the tissues to the physical chemical conditions of the inter-organic medium are responsible for the harmonious growth of the body. The cell metabolism and morphology depend on the quantitative and qualitative characteristics of the humors.

The short-circuiting of the circulation because of AVF's has a tendency to produce a venous stasis in the peripheral portions of the extremity involved, with a consequent lowering of the pH of the blood. The statement that there is an increase in blood supply can hardly be supported by the evidence at hand and does not seem to be in accord with the anatomic arrangement of the described anastomoses.

The studies of Peters and others (1926) revealed, among other changes, a reduction in the pH of the blood and the existence of relative acidity following upon venous stasis. Swindle (1935, p. 11) is also of the opinion that the reduction of the pH may be the most important factor in the stimulation of bone growth and soft tissue growth in these cases.

The observations on laboratory materials tended to confirm the observations on living AVA's in the rabbit's ear made by Clark and Clark (1934) and of observations of Grant (1930) made on the same tissue in injected and living preparations. It should be pointed out that the morphology of AVA's as described is varied and that not all varieties are found in every tissue. For instance, funnel types are more frequent in the rabbit's ear, while this was not the case in other tissues examined. Krogh (1929, p. 101) makes the criticism of the injection method that it does not lend itself to verification by a study of the structures of the vessels in question. In addition, he believes that single capillaries can easily become greatly dilated by injection under pressure and give the appearance of wide channels so that he thinks evidence of this kind is untrustworthy. Swindle (personal communication) believes that, with the method as used by him, this criticism is purely an academic one. Swindle believes that artifacts suggesting AVA's may be seen in injected specimens because of compression of veins by arteries. He states that he has never seen inflated capillaries following the proper injection of tissues except in cases where the blood vessels are hypertrophied. In the specimens injected and cleared by Swindle in which AVA's were seen, the evidence of the nature of these structures seemed so clear as to leave little room for argument.

The use of arteriography in the demonstration of AVF's promises to aid considerably in the diagnosis and treatment of this condition. In the case reported here the method did not enable us to localize the fistulas and it is probable, because of the nature of the congenital communications, their small size, and great numbers, that the method will be of limited usefulness. The possibility of this method being of value in the diagnosis of the existence of AVF's should be borne in mind when lesions occur in the extremities. The use of arteriography in the demon-

stration of AVF's occurring intracranially does not seem to be warranted because of the dangers attending the use of a contract medium in this region. The dangers apparently outweigh the value to the patient of any added evidence which may be so obtained. The dangers associated with the injection of large quantities of thorium dioxide are well recognized. The amount given in this case (thorotrast, 28 c.c.) is well within the limits and is considered as safe. Failure to demonstrate large communications or communications in association with the large trunks in the reported case do not negative the diagnosis. The diagnosis, in this case, rests upon the hypertrophy of the leg, the presence of dilated veins containing arterialized blood, and the increase in local skin temperatures.

The value of infra-red photography in the differential diagnosis of hemihypertrophy of the extremity is evident from the case here reported. The absence of dilated veins below the surface of the skin in the case of hemihypertrophy helps to exclude the presence of arteriovenous fistulas. The markedly dilated and tortuous veins demonstrated in the case of AVF's is important added evidence in establishing that diagnosis. Its use for this purpose has not previously been reported.

VI. SUMMARY AND CONCLUSIONS

A review of the literature indicates that the in situ theory of vasculogenesis is generally accepted among anatomists. The assumption generally held by physicians that our knowledge of the capillary bed is accurate and complete is incorrect. A resume of our knowledge concerning the capillaries is given here as a background for the discussion of the clinical phenomena observed in congenital AVF's. Our knowledge of the anatomy and physiology of AVA's is reviewed for the same purpose. Laboratory observations of injected blood vessels have been made in order to supplement the studies of clinical cases. These laboratory studies, in the main, supported the observations of Clark and Clark (1934), Grant (1930), and Grant and Bland (1931), previously referred to in this thesis. The presentation of a case of AVF's and a case of hemihypertrophy of undetermined origin involving the lower extremity demonstrates the value of infra-red photography as an aid in the differential diagnosis of hemihypertrophy of the extremities. The oxygen content of the blood, the increased temperature of the skin of the involved extremity, the venous dilatation, and hypertrophy of the soft tissues established the diagnosis of arteriovenous fistulas. Arteriography did not aid either in establishing the diagnosis or in locating the site of the fistulous communications in the case here reported.

On the basis of these studies the following conclusions have been arrived at:

1. The in situ theory of vasculogenesis is generally accepted as in keeping with observed facts.
2. Our knowledge of the anatomy of the capillaries is inadequate.

3. AVA's exist in various tissues as physiologic structures.

4. The function of physiologic AVA's is not known.

5. The relatively rare occurrence of congenital arteriovenous fistulas is noteworthy in view of the development of the blood vascular system.

6. Infra-red photography is of definite value in the differential diagnosis of the cause of hemihypertrophy of the extremities and as an aid in the diagnosis of arteriovenous fistulas.

7. The cause of the increase in length of bones and of hypertrophy of tissues in congenital AVA's is not known. It is probably due to venous stasis and the resulting decrease in the pH of the blood.

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Review of Recent Meetings

REVIEW OF THE FORTY-SIXTH FRENCH CONGRESS OF SURGERY, OCT. 4-9, 1937, PARIS*

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PIERRE DUVAL (Paris), and **Mourgues-Molines** (Montpellier): **The Pathologic Physiology and Treatment of Recent Extensive Cutaneous Burns.**—The authors refer to extensive burns as those belonging to the second and third degree groups, according to Dupuytren's classification (vesicle formation and necrosis), involving at least one-third of the cutaneous surface, during the period of intoxication between the fourth and tenth days.

Pierre Duval (in collaboration with **J. C. Rudler**): I. *Physiopathology.*—The author calls attention first to the frightful mortality of extensive burns and to the fact that the seriousness of the burn varies in direct proportion with the calculated involvement of the body surface. He adopts for this calculation the table of Berkow. The personal statistics of the author are based upon 16 observed cases in six months. Fifteen died, 60 per cent dying in the first six to twenty-four hours.

II. *The Clinical Picture.*—This is described as essentially a period of excitation (agitation, mental disorientation, convulsions) followed by a period of somnolence which ends in coma (with myosis and Cheyne-Stokes' respiration) and death. Emaciation appearing on the fourth to the fifth day is a bad prognostic sign. The blood pressure is generally low and the pulse is very rapid. Urine is scanty, although occasionally it is normal in quantity. The temperature is not infrequently low at the onset. On the third or the fourth day there sometimes appears a marked hyperpyrexia which the author explains by the particular action of the circulating toxins in the blood on the central thermal regulating center.

III. *Pathologic Anatomy.*—The author describes in detail the classical anatomicopathologic lesions in the involved cutaneous areas and in the viscera.

IV. *Physiologic Chemistry.*—The biologic reactions are carefully reviewed by the author. The increase of blood concentration is indicated by increase in the red blood cell count, by an increase in the hemoglobin and the refractometric index. The coagulation time seems to the author to be increased and the bleeding time is diminished. The author particularly studied the polypeptids. Characteristically they were increased to double the normal (0.0250-0.0260 gm. per liter of blood). This increase begins about the sixth hour and is in general proportionate to the extensiveness of the lesion. There are some exceptions to this rule as sometimes these findings were normal. The uric acid of the blood is regularly increased. The blood chlorides, as has been shown by Davidson, are constantly low. This is accompanied by a low chloride content of the urine and is due to the fact that the chlorides are fixed in the brain tissue as well as in the unaffected tissues (in fact, the chlorides of the healthy skin of the burned patient are equally increased). Hyper-

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glycemia is the rule and seems to be due to the presence in the blood of disintegrated albumin. Acidosis is constant and proportionate to the extensiveness of the burn.

As regards the adrenalinemia, the author calls attention to the fact that there is a transient augmentation followed by a notable diminution due to the anatomic lesions of the organ. Rudler and Meunier made studies of the content of the ascorbic acid and observed figures of 10 instead of 35, while the glutathione was zero. As regards the toxicity of the blood, the authors call attention to the studies of Vogt and Vaccarezza and the study of Kotzareff. The latter showed that the blood of previously burned patients may have an antitoxic property.

The urine does not appear always to be changed as the author has seen dying patients with extensive burns and a normal excretion of urine. He calls attention to the fact that if there exists urinary retention these patients will respond very well to diuretics. The polypeptids and the amino acids are increased. The author notes the presence of creatine in the urine and the presence of an abnormal increase of creatinine. Glycosuria is frequent. Like Goiffon, he was able to demonstrate the presence of sodium bicarbonate in the urine towards the third to the fourth day.

The pathogenesis is explained by the author as the following: The heat in attacking the tissue albumin produces a quantity of highly toxic proteins which are carried by the veins to the entire body. The quantity is proportionate to the mass of tissue destroyed. Thus, the local lesion can become generalized because of the toxic substance produced in the involved area and carried to the remainder of the organism by the blood stream. Evidence of the breaking down of the albuminoids is the increase of toxic substances in the blood such as polypeptids and uric acid. This toxic stage lasts, in general, until the fourth to the sixth day. It ends in death or by gradual return to recovery. The methods of body defense are the following: (1) the liver destroys certain toxic substances such as the polypeptids by transforming them into urea; (2) the lungs excrete amino acids; (3) a certain proportion of the toxic substances is eliminated in the urine; and (4) fixation of the blood chlorides.

The real nature of the toxic substances is unknown. For the present it suffices that the toxic substances originate in the burned tissue derived from the cellular albumins belonging to a group of polypeptids. From the biologic studies of the author, the following prognostic criteria are given: Increased nitrogen content of the blood with normal or slightly elevated polypeptids suggests a good prognosis. Normal blood nitrogen with increased polypeptids suggests a bad prognosis. Elevated blood nitrogen with elevated polypeptids suggests a doubtful prognosis.

Mourgues-Molines, Montpellier: **The Treatment of Recent Extensive Cutaneous Burns.**—"The idea of preeminence of general treatment over localized treatment in the therapy of extensive burns is perhaps the most effectual progressive step in twenty years."

I. *The General Treatment.*—Combating the toxemia. For pain the author recommends morphine except in infants for whom codeine or chloral is preferred. Heat should be applied to the patient and substances should be given to combat the hypotensive collapse (author prefers ephedrine). To combat the increase of blood concentration due to the enormous loss of fluid in the region of the burned area resulting from an abnormal permeability of the capillaries, it is necessary to resort to intravenous injection of isotonic saline (4 to 5 L. per day appear sufficient). It is necessary to combat the hypochloremia (in accord with the investigations of Davidson) and the increase in polypeptids of the blood by giving 100 c.c. of hypertonic saline (10 per cent) daily. Blood transfusion is often useful. The author prefers repeated small transfusions of 200 to 300 c.c. The presence of toxic granulations of

Fasal indicates the practicability of transfusions. The usefulness of convalescent serum is not established. The author refers to the good results obtained by Wilson by the administration of large doses of suprarenal cortex extract.

II. *The Local Treatment.*—The author makes a detailed study of this. A careful disinfection of the wound should be done first as was indicated by Nageotte-Wilbouchewitch in 1893. The author refers in detail to the different methods utilized in combating the intoxication, such as excision (which the American authors designate under the term "débridement" which is actually incorrect), or the method of continuous baths of Hebra (Wasserbett), or the method of desiccation of the burned surface by the exposure to free air. He considers the tannic acid method of Davidson as the best. He reports in detail the history, the technique, and the excellent result. As successors of tannic acid, he mentions silver nitrate, perchloride of iron, gentian violet, mercurochrome, and brilliant green.

The author states that the following methods are advocated to stimulate cicatrization after the removal of the tannate crust: wet compresses of Dakin's solution, local application of cod liver oil, and ultraviolet rays. In conclusion the author proposes tannic acid as the most rational type of treatment, except in burns of the face which heal very well by simple exposure to air.

Discussion.—**McClure** (Detroit), by invitation of the Congress, showed a beautiful film from the Henry Ford Hospital demonstrating the manner in which the tannic acid treatment is practiced there. Some patients with 55 per cent of the body surface burned have recovered.

Riehl (Vienna), invited by the Congress, stated that he treated burns with transfusions without tannic acid. Sixty per cent of the burned cases recovered. After a discussion on the morphologic modifications of the blood, he spoke on the treatment by continuous baths (Wasserbett) originated by **Hebra**, Vienna, which had certain advantages, particularly the preservation of articular mobility.

Wilson (Edinburgh), invited by the Congress, stressed the usefulness of cortin to combat the toxemia.

Von Seemen (Munich), invited by the Congress, suggested the use of the electrosurgical unit in the burned region for its mechanical cleansing effect, and added that after clinical and experimental investigations he noted a marked diminution of the absorption of toxic products.

Mario Donati (Milan) reported particularly on the mass of circulating blood which he found to be modified. He observed a progressive and proportional diminution of the plasma. There is also a reduction of the number of formed elements of the blood. Whereas the quantity of circulating red blood cells returned to normal, the oligocytosis persisted. The loss of plasma is produced when the blood traverses the burned region. These facts are of extreme importance, according to the author, in the early stage. He states finally that tannic acid is not antiseptic and this has led him to use certain modified solutions.

L. Christophe (Liège) interpreted the diminution of blood chlorides as due to an escape from the blood stream into the tissues.

Dziembowski (Bydgoszcz) reported on the treatment of burns by the local application of vitamins.

R. Leriche (Strasbourg) called attention to the use of sterile sheets. He considers tannic acid as the best treatment, but not in all cases, and since 1926 he has employed mercurochrome in infants and in burns about the face. Mercurochrome is especially recommended for infected burns.

J. deFourmestraux (Chartres) reported on burns of aviators. These patients die of bronchopneumonia or of pulmonary gangrene resulting from the gas due to the burning of gasoline. He reported a case in which he noted an absence of oliguria.

Hamant (Nancy) and **Grimant** (Algrange) reported on their interesting observations in which they resorted to the immediate excision of the burned region.

Yves Bourde and **Roger Gary** reported on 25 cases of burns which they studied. They called attention to some cases of burns in children who have presented a syndrome very similar to the syndrome of hyperpyrexia of nutrition. They advocated in these instances the use of cold applications. In the infected cases they resort to mercurochrome.

P. Lombard and **Montpellier** (Algeria) reported on the histologic findings of two interesting observations. In the first case a child of seven years of age having a burn occupying more than 50 per cent of the body surface died twenty-seven hours after the accident. Histologic examination disclosed only lesions of the tubules of the kidney. On the other hand, in the second case, which was a child of twelve years of age having a normal blood nitrogen, they noted a characteristic glomerulo-nephritis. They also noted degenerative lesions of the liver.

Paul Piollet and **H. Limousin** (Clermont-Ferrand) have employed vitamin A. which they believe diminishes the toxicity and favors cicatrization. In some cases they first applied mercurochrome and then compresses of cod liver oil.

Yves-Delageniere (Le Mans). These authors still employ alcohol dressings which was taught them by their former chief, Lecene, and which they employ under anesthesia of ethylene chloride. They call attention to the fact that the practicing physician, nurses, attendants, etc., should be instructed against the immediate application of oil or grease in cases of burns. The manuals of first aid should be corrected in this regard and advocate dry sterile dressings as the best immediate form of therapy before sending the patient to the surgical service.

Chevallier and **Carcassonne** (Marseilles) reported very favorable results with the use of vitamin A. They believe that it favors cicatrization and elasticity of the scar, which they believe is important, especially in the region of the articulations.

J. Fiolle and **T. Funck-Brentano: Arterial Emboli of the Extremities—Physiologic Pathology and Treatment.**

J. Fiolle: The Physiological Pathology of the Arterial Emboli of the Extremities.—After having rendered respect to the work of René Leriche, the author then discussed "lost" (manquée) emboli and "occult" emboli. The "lost" (manqueé) emboli are those which, after having a sudden and dramatic onset, go on toward recovery without having provoked gangrene. The "occult" emboli are those which are not suggested by any signs indicative of embolus. These types are of interest, because they may indicate a possible mechanism of defense.

The author referred to the possible origin of emboli (thrombi originating from the heart or aneurysm, atheromatous plaques detached from an arterial wall). The author with his student, Haimovici, found that septic emboli play a most important rôle in coagulation. Whereas in 10 experimental aseptic emboli there was no important thrombosis except a clot of 2 or 3 cm., of 7 septic emboli in the dog there was extensive thrombosis extending towards the periphery from the point of obstruction.

The parietal lesion in the region of the embolus involves the intima (epithelial desquamation), very little of the media, but especially the adventitia (active endo-

thelial capillary reaction and considerable polynuclear infiltration). These lesions of arteritis are early and progressive and after the twelfth hour render embolectomy and suture of the arterial wall unlikely to be successful.

The most important factor in the pathologic physiology of emboli is the vasomotor reaction. Haimovici in his experimental investigations introduced into a vessel a small dilatable balloon which consisted of a segment of the jugular vein, having one extremity closed and the other extremity connected to a tube through which a variable quantity of fluid could be injected to inflate the balloon. He observed that there was no vasomotor reaction if the obliteration was incomplete, nor if the balloon was slowly dilated to produce complete obliteration. On the other hand, sudden complete distention produced a marked vasomotor reaction. These vasomotor reactions consisted of a spasm in the region of the obstruction in the artery. There is always spasm in the obliterated segment and in the distal branches of this segment in the arterioles and even the capillaries. This spasm could extend over to the collateral vessels and make itself manifest in the neighboring vessels even at a distance. The author calls this "arterial colic" and refers to the pain accompanying the vasoconstriction of the segment as such.

The pathway followed by the vasomotor reflexes passes by the way of the perivascular plexus which Leriche has pointed out and by the mixed nerves (Malmejac and Haimovici). The origin of the reflex is perhaps in the endothelium, but it also may be in the adventitia. The author noted that some extensive thrombi could become enormous and completely out of proportion to the original embolus. The mechanism of this formation consists of lowering of the blood pressure distal to the embolus and stagnation of blood.

The collateral circulation may be formed by the long arterial anastomosis or by the numerous intermuscular branches. Following the occurrence of the embolus the collateral supply may be developed with some difficulty. The author calls attention to the fact that the dangerous zones are the bifurcations and in the zones where there is a juxtaposition of muscles with divergent insertions (Leriche).

The first period which follows the embolus is that of initial shock and is dominated by the vasomotor reaction (spasm). If the embolus is not too large or too infected, the spasm ceases. The collaterals enter into play and the embolus becomes a "lost" embolus. However, most cases enter into the second period, which consists of parietal alterations and extensive thrombosis. The deeper arterial lesion is followed by a periarteritis (Leriche). The third period is that of complications and is dangerous because cicatrization does not mean recovery.

P. Funck-Brentano: The Treatment of Arterial Emboli of the Extremities.—Having recalled the work of Professor René Leriche, which is of prime importance in the rational treatment of emboli, the author divides the therapy into two groups. First, the anatomic method directed toward the embolus; second, the physiologic pathogenic method directed toward the sympathetics of the arteries. These two methods must not oppose each other, but they should be complementary.

The author first discussed the anatomic basis of the surgical treatment of arterial emboli. From experimental, clinical, and bacteriologic investigations it appears that in contact with the clot there is produced an endarteritis. The time of appearance of this endarteritis is variable. If the clot is large or septic, it appears early. This does not occur if the embolus is aseptic, if the obliteration is not complete, or if the collateral is immediately developed sufficiently. As a general rule, if the embolus is caused by a septic cardiac lesion, the time of appearance of the endarteritis is about ten hours.

The author next discussed the diagnosis of arterial emboli. There is marked pain which is very intense and localized in the involved area, but which may be diffuse and involve the entire extremity. This pain is due to the irritation of the

periarterial sympathetics by distention of the vessels (Leriche). The suddenness of the appearance of these signs is not constant and in a large proportion of cases the beginning is progressive. There is also pallor and coldness of the skin and a disappearance of skin sensitivity. The pulse is not perceptible and the reflexes are absent.

In the differential diagnosis phlebitis and arteritis must be considered. It should be recalled that phlebitis can produce the syndrome of arterial ischemia by an arterial spasm.

The differentiation between embolus and thrombosis of the artery by arteritis is also important (Einar Key). The presence of infection or intoxication is in favor of thrombosis. The presence of a cardiac lesion is in favor of embolus. In the case of embolus the oscillometer of Pachon shows an increased arterial pulsation above the obliteration and a diminution immediately below. On the other hand, in the case of thrombosis the diminution of oscillations is progressive. One can differentiate the embolus from arterial thrombus by the use of warm baths and by the use of vasodilators such as acetylcholine.

The diagnosis of the embolic attack is of very great importance. All of the authors are in accord in insisting on the frequency of the localization of the embolus at the points of bifurcation. Certain clinical observations such as the attack of pain, the thermal modifications, the signs of ischemia, and the pulse permit the localization of the embolus to a certain degree. But the most exact and useful method for the localization of the embolus is the arteriogram, which demonstrates precisely where one must intervene, indicates the number of emboli, and offers some information of the degree of collateral circulation.

In the absence of any therapeutic measures in cases of arterial emboli gangrene has been observed in 73 per cent of the cases if the subject is more than sixty years of age, and in 32 per cent of the cases if the subject is less than sixty years of age. There are some emboli that heal spontaneously. In other cases healing is incomplete, but usually gangrene develops.

As regards the therapeutic methods, the author begins by a discussion of the methods which attack the embolus. Embolectomy was successfully practiced for the first time in 1911 by the French surgeon, Georges Labey, but the Scandinavian surgeon, Einar Key, has been the leading pioneer of this form of therapy. This author published in 1923 the results of 36 embolectomies with 16 successful results. According to the present author the number of embolectomies published is 404. Of 108 observations published since July, 1932, the percentage of successful results on patients operated upon before the tenth hour was 70. The author discusses in detail the technique of embolectomy and insists upon the necessity of uncovering a large portion of the artery, of strict asepsis, and of employing an anticoagulant material (he prefers 2 per cent citrate solution).

The technique of embolectomy was discussed in considering the larger arterial trunks, such as the subclavian which can be exposed best in the hollow of the axilla, and the bifurcation of the aorta or the primary iliacs, which can be approached by the transperitoneal, retroperitoneal, or femoral route (Einar Key), and finally by the combined femoral and retroperitoneal routes.

Embolectomy is considered successful only if the permeability of the principal arterial trunk is reestablished. Absence of necrosis of the extremity is not sufficient. There must be reappearance of the arterial pulse. One of the arguments given by numerous authors against embolectomy is secondary thrombosis at the line of the suture. Actually, after embolectomy the thrombus is not the result of the method but the manner in which it is done. The thrombus is not the result of arteriotomy but of the preexisting endarteritis.

The mortality in general is sufficiently high. The author cites the work of Pearse which is based upon 296 embolectomies of which 52 per cent died less than a month after the operation. The late deaths are the result of the original lesion (chronic myocarditis, embolus, or cerebral hemorrhage, etc.).

A study of the results according to the age of the subject shows that an advanced age is not a contraindication to embolectomy and that a young age is not always a factor of good prognosis. As regards the arteries involved, the results are clearly better in interventions on the upper extremity than in those of the lower extremity, and in interventions on the superficial arteries than in those of the deeper arteries.

The time of the operation plays the principal rôle in the prognosis. The earlier the intervention after the occurrence of the embolus, the less is secondary thrombosis likely to occur. Reports on the statistics of the author (1932-1937) on 108 cases is in accord with the statistics of Key, of Pearse, and of Danzis. In those cases in which operation was performed within ten hours after the occurrence of the embolus, there were 70 per cent successful results. After the tenth hour on 26 cases there were only 6 good results.

The author concludes that if the procedure is applied in those cases in which it is definitely indicated embolectomy presents more advantages than disadvantages, and that in the future the successful results can be increased by the use of arteriography to localize precisely the site of the embolus and by adding a complementary procedure (sympathectomy or paravertebral novocaine infiltration of the sympathetics).

The author then discussed arteriectomy. This operation is based upon the knowledge of the physiopathology of the obliterated artery and the investigations of René Leriche. The procedure suppresses an irritative focus which obviates peripheral vasoconstriction.

The author discusses the technique of arteriectomy before and after embolectomy and concludes that it is preferable to do first ablation of the embolus and following this resection of the artery in the zone where the endothelium is involved.

In studying the indications for arteriectomy and for embolectomy, the author comes to the following conclusions: Before the tenth hour it is always necessary to do embolectomy; after the tenth hour arteriectomy is indicated. He advises exploratory arteriotomy in the late cases approaching the tenth hour. On the other hand, when it is later than this, he advocates arteriectomy without previously opening the artery. Furthermore, arteriectomy is indicated if the patient is very weak and incapable of withstanding a long intervention, such as embolectomy on one of the larger vessels, and if the embolectomy has failed in the instance where extirpation of the clot is impossible or where there is secondary thrombosis.

The intervention of the sympathetics consists of novocaine block or ablation of the communicating rami or the ganglia. For the lower extremities he advises the extirpation of the second, third, and fourth lumbar ganglia which gives the most intense vasodilatory action. For the upper extremity he advocates novocaine infiltration of the stellate ganglion, as described by Leriche.

Venous ligation has been advocated in the case of arterial obliteration by von Oppel who showed, in 1910, that it can produce an increase in the blood supply after ligation of the corresponding artery. In the light of the work which he discussed it is not considered an advisable procedure.

The author discussed in detail the pharymicodynamic treatment. He particularly studied the antispasmodic action of papaverine and the vasodilatory action of acetylcholine and of other sympathicolytic drugs (Yohimbine). He stated also that certain cardiac drugs are useful in relieving the peripheral circulation. But in general the medical treatment must simply be an aid to the surgical.

Finally the author discussed passive vascular exercise used particularly in the United States. The method has not escaped considerable criticism, and as yet the number of observations published limits its evaluation.

Discussion.—**Jean Dedrna** (Hradec Kralové) discussed the rôle of the lumbar sympathetics in the treatment of arterial embolectomy of the lower extremity.

F. Albert (Liège) stated that he always used infiltration of the lumbar sympathetics and vasodilatory drugs. As a result of his studies on the origin of peripheral vasoconstriction, he believes that venous ligation is indicated in certain types of cases.

Reynaldo dos Santos (Lisbon) discussed three points: (1) The importance of the extensiveness of spasm. He cited a case with endocarditis and gangrene of the nose and possible gangrene of the ears in which he noticed a marked cyanosis of the extremities which was suggestive of emboli of cardiac origin. Novocaine infiltration of the stellate on both sides immediately resulted in improvement. Later, autopsy confirmed the fact that there was no embolus and that the vascular disturbance was uniquely of spastic origin. In each type of case infiltration of the sympathetics with novocaine is extremely important. (2) Arteriography cannot show all of the arterial lesions. He has observed an extensive nodular syphilitic periarteritis which clinically had simulated embolus in a case in which the arteriogram was normal. Furthermore, by making two exposures with a slight interval between, each arteriography can show not only the proximal but also the distal limits of the obliterated artery. (3) As regards treatment he has a tendency to revert to the use of venous graft which he believes has the immediate advantage of counteracting the drop in pressure in the distal segment. He has been able to demonstrate persistence of circulation in the graft several months later by arteriographic examination. He believes that the graft is particularly indicated in the cases where the parietal lesion cannot be affected by simple embolectomy.

René Leriche (Strasbourg). Clinical observation, arteriography, and particularly the initial pain clearly indicate that much of the disturbance is due to the endothelial lesion, while some is due to the adventitia. On the basis of clinical investigations and in variance with the views of English and American authors, as well as Malmejac and Haimovici, he contended that there exists a certain nervous conduction along the artery.

As regards the diagnosis, he believes that it is impossible to distinguish embolus from thrombus. The clinical signs and the suddenness of the symptoms are insufficient to establish embolus. Furthermore, he does not believe that arteriography can absolutely make the diagnosis. The most important diagnostic aid is to keep it constantly in mind. With the full realization of the frequency and importance of arterial spasm, Leriche cautions the surgeon not to make this diagnosis too eagerly, but to examine carefully for its presence.

As regards treatment he states that embolectomy aided by previous novocaine infiltration of the sympathetics is the ideal method. In the surgical treatment he states that it is important to visualize the artery. At one time he tried performing grafts after excision of the obliterated arterial segment. In his experience this has not been successful. But he believes that it is indicated today, because the patients are seen earlier, as dos Santos has noted.

Leriche believes that one can resect all of the arteries of the extremities except the aorta and the innominates. However, one should be careful in the resection of the bifurcation of the humoral artery and the origin of the tibioperoneal trunk. The arteriectomies which give least clinical results are those of the smaller vessels.

In spite of all treatment amputation is often necessary. But it is undeniable that operations on the arteries and sympathetics limit considerably the extent of the necessary sacrifices.

T. Wertheimer (Lyon) reported 3 interesting cases. He insisted upon the importance of arterial spasm and novocaine infiltration of the sympathetic chain.

Carcassone and Haimovici (Marseilles) related their interesting experience regarding the mechanical and vasomotor or spasmodic factors of the obliteration. They emphasized the importance of counteracting the spasm in the first stage by the use of vasodilator substances or novocaine infiltration of the sympathetics and arteriectomy for the arteritis in the second stage.

Marc Iselin (Paris) reported his observations on 4 recent cases and stressed the relative independence of function between the arterial trunk and the arterioles.

Naulleau insisted on the usefulness of arteriography and the therapeutic importance of the infiltration of the sympathetic chain. By graphic means he has proved that these infiltrations must be frequent and repeated.

R. Merle D'Aubigné and **Jean Creyssel: Relative Indications for Surgical Intervention and for Orthopedic Methods in Closed Fractures of the Leg.**—The authors reviewed the anatomic characteristics of fractures of the leg and distinguished two groups for diaphyseal fractures of the leg: transverse fractures and spiral fractures. The old group of oblique fractures should be classified under the first or second group according to their etiologic characteristics and radiologic findings.

The authors then discuss the anatomic results and the functional results. Is anatomic healing necessary to obtain a good functional result? The study of numerous statistics, including those of the authors, showed very well that there is a parallel between the anatomic state and the functional result. The following are the statistics of the authors on 219 observations: Of 68 perfect or very good anatomic results there are 67 perfect or very good functional results. In the other cases in which the anatomic results were poor, the functional results were also imperfect: 4.3 per cent if there was an overriding or overlapping of 2 cm.; 42 per cent if there was slight angulation; 80 per cent if the shortening was greater than 2 cm., even with a good axis. This shows the necessity for obtaining the best possible anatomic restitution.

The authors then discussed the best methods of treatment: (1) the classic orthopedic treatment; that is, manual reduction with application of plaster cast is insufficient because of the frequent secondary displacement, especially in spiral fractures; (2) the application of a Lane plate or wiring has the well-known disadvantage of infection and delayed healing; (3) the modern orthopedic method; that is, the classic orthopedic methods with various appliances: continuous transosseous extension (Putti, Kirschner); the fixation by transosseous wires included in the plaster cast (Böhler).

They then describe their personal method for spiral fractures, which consists of fixation by the double pin (Creyssel and Colson), and the pin method of Merle D'Aubigné. The authors, in comparing the results obtained by the various methods, note the following: (1) the risk of infection by Kirschner pin or by transcutaneous fixation is much less than by open reduction and metallic fixation; (2) the duration of the treatment according to the authors' observations is about five months by the old classic method if successful, but if it fails and it is necessary to employ some other technique the time increases to twelve months. It is about seven months by the Parham-Martin band method, but only four months by the wiring method

of Danis. It is about six and one-half months by plaster of Paris with the enclosed pin (technique of Böhler). Finally by the transosseous fixation (Creyssel and Colson, and Merle D'Aubigné) it is four and one-half months; (3) the anatomic and functional results following these methods are: In the spiral fractures the classical orthopedic method (plaster of Paris) gives only 60 per cent good functional results. The modern orthopedic method (transcutaneous fixation) and the Lane plate method give very good results, 85 per cent for the bone plate, 80 per cent for the method of Böhler. In the transverse and oblique fractures the classic orthopedic method gives 66 per cent good results and the bone plate method 76 per cent good results. The authors note that the modern orthopedic methods do not give better results.

The authors then give the general indications. Transcutaneous fixation is advocated for recent spiral fractures. If there are counter-indications (a bad condition of the skin), continuous extension is employed. If the reduction is imperfect, especially if the fracture is seen two weeks after the accident, the wiring method of Danis, the screw fixation of Merle D'Aubigné, or the Kirschner method (Creyssel) is best.

For transverse or oblique fractures, it is preferable to employ closed reduction and continuous extension in the plaster. If the reduction is impossible continuous extension or open reduction is necessary.

M. R. Danis (Bruxelles) stated that in order to reduce operative trauma and to induce good healing open fixation is considered as the method of choice and not as a last resort. Furthermore, it is necessary to avoid prolonged immobilization of the articulation above and below the fracture. For this reason he immobilizes the leg in a metal and cloth legging surrounded with celluloid which can be laced on so as to permit the knee and the ankle to be free. The bone fixation of the leg is made with a steel wire which is wound around the fragments. Spiral fractures are particularly adaptable to the wiring method and the results on 28 cases reported by the author treated by this method were excellent. In the transverse fractures the method is more difficult to employ and the results in 25 cases were considerably less favorable. In the latter types splinting by a graft of pure bone appeared to him to be a better method, because he has obtained excellent results in the cases in which he has employed it up to the present.

Discussion.—**Lambotte** (Anvers) discussed the open operative method.

Beuver (Namur) and **Berburge** (Anvers) prefer external fixation.

Jacobovici (Bucarest) described a ribbon encircling method with external fixation (Juvara), which easily permits the removal of the metal.

Leriche (Strasbourg) after having seen and employed various methods stated that he realizes more and more the advantages of metal fixation of the bone and prefers this method when an attempt at reduction has failed.

Stulz (Strasbourg) reported excellent results by open fixation on 30 cases in the clinic of Professor Leriche.

Chiarolanza (Naples) preferred closed reduction.

Petre Topa (Bucarest) stated that he prefers the open method and fixes the bone by the simple graft of Jacoel which he removes on the fifteenth day.

Podlaha (Olomouc) stated that he prefers the orthopedic treatment and reserves the open fixation for the cases where this fails.

Auvray (Paris) having examined a number of cases noted that bad results of bone fixation methods are possible and that it must be employed with judgement by a qualified surgeon.

Fredet (Paris) preferred the open fixation method.

Judet (Paris) tries first the orthopedic method and if this fails he uses open fixation.

Dupuy de Frenner (Paris) uses the closed reduction method for cases seen early.

Others taking part in the discussion were **Arnaud** (Saint-Etienne), **Lemaire** (Courriere), **Vanlande** (Rabat), **Marcel Senechel** (Paris), **Chevanez** (Bordeaux), **Pastalis** (Paris), **Delandeninert** (Mons), **Masmontille** (Paris), **Grinda** (Nice), **Serey** (St. Malo), **Rieneg** (Toulousse), and **Gentile** (Nodent-sur-Marne).

REVIEW OF THE MEETING OF THE ASSOCIATION OF AMERICAN MEDICAL COLLEGES, SAN FRANCISCO, CALIF., OCT. 25-27, 1937

C. D. Creevy, M.D., Minneapolis, Minn.
(From the University Hospital)

THE forty-eighth annual meeting of the Association of American Medical Colleges was held at the Fairmont Hotel, San Francisco, Calif., on October 25 to 27, 1937.

Dean E. W. MacEwen, of the Medical School of the University of Iowa, gave the first of four papers in a symposium on examinations. He pointed out that increases in the number of medical students have lessened individual contacts with instructors and enhanced the importance of the written examination. The fact that 25 per cent of the students admitted to our medical schools fail to finish suggests defects in the current system of examinations, but points also to inadequacies in selecting the students in the first place. The remedy for this high student mortality probably lies also in the selection of better teachers, bearing in mind that an excellent research worker may be a miserable teacher; and in improving the type of examination, perhaps by a shift to the objective form.

Dean H. S. Diehl, of the University of Minnesota, described the system of comprehensive examinations employed in the Medical School there for the past ten years. The questions are prepared by the various departments, reviewed by the examination committee for ambiguities and unfairness, and given annually, except in the fourth year, under the supervision of the chief examiner. Papers graded below passing are checked by a second examiner and, if still below grade, by the committee. The names of the students are not known to those correcting the papers. The student may repeat both the freshman and sophomore examinations once and may have three trials in the junior year. More failures than this lead to dismissal. The work of the next year may not be taken, in whole or in part, until the comprehensive examination of the preceding year has been passed.

Chief advantages of the system are its impartiality, the fact that the disturbances of students and faculty incident to examinations occur only once a year, and the necessity for reviewing the whole year's work as a unit. Moreover, the practice of rechecking the low papers insures fairness to the weak student. In the years 1935-1937, about 10 per cent of those taking the examinations were eliminated.

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Dr. R. C. Sears, of the University of Oregon, described their system of examinations which is patterned after that of the University of Minnesota except that the committee is empowered to disregard failures and promote the student if it chooses to do so.

Dr. Robert P. Dobbie, of the University of Buffalo, presented a type of objective examination designed to eliminate inequalities in the grading of papers by so phrasing the questions that they are answerable by "yes" or "no" or by simple enumerations, yet extensive enough to serve as a real test of knowledge. Development and adoption of this type of examination was prompted by Dobbie's previous observation that, in correcting the essay type of examination, different examiners gave very different grades for the same answer; and the same examiner regrading the same paper after a considerable period without a record of the previous grade was very inconsistent.

With the new type of quiz, the average difference between examiners grading the same paper was one point: with the previous type it had been as high as 35 points.

Dr. E. Stanley Ryerson, of the University of Toronto, urged that more emphasis be placed in medical schools upon the recognition of the healthy state and upon its maintenance. Thus, courses in physical diagnosis of the normal person could well be begun, and closely integrated, with those in anatomy and physiology.

The second day was occupied by description of the organization of the curriculum at the Medical Schools of Leland Standford and of the University of California. Reflected was the increasing tendency to introduce the student to clinical work early in his career, both schools starting it in the sophomore year.

Dr. George Barnett, of Stanford University, emphasized the value of sophomore clinics consisting at each session of a brief explanatory lecture followed by practical work with patients.

Dr. Frederick L. Reichert, of Stanford University, described the course in dog surgery given to sophomores. The main purpose of this course appears to be to teach the student early how to comport himself to the operating room so that he will not be a menace to the patient when he begins to help with operations on the human.

Dr. William Dock, also of Stanford University, took the position that the pathologist ought to concern himself with gross and microscopic pathology, leaving the clinical aspects largely to the clinicians.

Dr. Salvatore P. Lucia, of the University of California, discussed the organization of the senior curriculum at the University of California, emphasizing the use of the out-patient department which has been so organized that the student follows the patient into the hospital or into the home, as the case may be, thus securing a view of the patient which includes the social and economic as well as the clinical aspects of his situation. The object is to avoid a narrow view of the patient's ailment.

Dr. Frederick S. Bruckman, of the University of California, discussed further the importance of the out-patient clinic in teaching and especially emphasized the value of the time spent by the student with the social service workers, from whom he learns at first hand of the organization and function of the various welfare agencies and how to enlist their aid when necessary. An attempt is made to familiarize the student with the various items in the cost of medical care.

The third day began with a symposium on the community aspects of medicine. **Dean H. R. Wahl,** of the University of Kansas, attributed the new conditions

which confront the practitioner of medicine to changes in the social order brought about by the machine age, and especially to swift transportation and communication. He declared that prejudice against the medical practitioner, always fostered by the cultists, is often increased by the physician himself through insufficient participation in civic and community activites, apparent snobbishness, lack of sympathy, and excessive fees.

He urged that students be informed of the medical aspects of social security legislation already in effect, and made conscious of modern needs and facilities for the care of the indigent and near-indigent. He pointed out that, in the long run, society will choose for itself the type of medical care which it desires.

Dr. B. W. Black, of Alameda, Calif., entered a plea for unprejudiced presentation to the student of such widely divergent but controversial matters as contraception, euthanasia, health insurance, and state medicine. He declared that the present economic system is incompatible with the current code of medical ethics.

Mr. Ralph Couch, of the University of Oregon, pointed out that it is difficult if not impossible to teach a medical student to be ethical, since his tendency in this direction has probably become fairly well fixed by other factors and training prior to entering medical school. He is sure that socialization of medicine is on its way and urges that students be prepared for it by teaching all the details of medical economics, including bookkeeping, his responsibility to charity patients, the details of the income tax law, etc.

In the discussion, **Dr. Herman G. Weiskotten,** of Syracuse, N. Y., said that at Syracuse University they had approached the economic problem by requiring each student to make a complete social and economic study of one patient and to present the result at a seminar with the social service worker and the professors of medicine and psychiatry. They have also initiated a six weeks' clerkship in Public Health, during which the student not only visits but participates in the activities of the various public health and welfare agencies.

Dr. Langley Porter, Dean of the Medical School of the University of California, deplored the present-day tendency to forget that the medical student is an adult who has rights to some leisure for reflection after exposure to stimulating teachers. Students are usually better aware of practical economics than one might think and should be allowed to draw some conclusions of their own rather than to be too tightly crammed with facts in formal courses.

Dr. Alan M. Chesney, of Johns Hopkins University, said that Johns Hopkins employs a plan similar to that described by Dr. Weiskotten.

Dr. Calvin P. Stone and **Dr. George S. Johnson,** of Stanford, University, presented the case for more adequate teaching of psychology to the premedical student and for its closer integration with subsequent studies of psychiatry by medical students. There was some deploring in connection with the small amount of time now devoted to psychology in the premedical curriculum and to psychiatry in the medical schools, leading the author to speculate idly upon the probable length of the medical curriculum if the pleas of each specialist for more emphasis and more time for his subject were heeded.

Dean M. H. Rees, of the School of Medicine of the University of Colorado, described Ebaugh's method of teaching psychobiology by means of personality studies of each freshman medical student, who is required to answer in detail an alarming array of questions (occupying twenty-four mimeographed sheets) concerning his past life and the intimate details of his behavior. While this must give the student an admirable insight into psychiatric methods, one cannot help but fear its effects upon the neurotic student with but little sense of humor.

THE CENTENNIAL MEETING OF THE AMERICAN ASSOCIATION OF OBSTETRICIANS, GYNECOLOGISTS AND ABDOMINAL SURGEONS, HOT SPRINGS, VA., SEPT. 20-22, 1937

JENNINGS C. LITZENBERG, M.D., MINNEAPOLIS, MINN.
(From the University of Minnesota)

THE meeting of the American Association of Obstetricians, Gynecologists and Abdominal Surgeons, held at the Homestead Hotel, Hot Springs, Virginia, was the Centennial Celebration of the founding of the Society. It was held on September 20, 21, and 22.

Improvements in the Operative Treatment of Carcinoma of the Large Bowel, W. Wayne Babcock, M.D., Philadelphia, Pa.: Dr. Babcock called attention to the advantages of oblique muscle-splitting incision in resection of the large intestine for carcinoma. He discussed the prevention of peritonitis by preliminary decompression of the bowel, by vaccination of the peritoneum, and by semiaseptic methods of suture; the guarding of suture lines from peritoneal leakage by large glass tube drains; modifications of the Mikulicz operation with immediate drainage by external bulbous tubes; early division and suture of the spur with the aid of fine alloy steel wire sutures and ligatures; the removal of rectosigmoid growths by a modified abdominal Mikulicz procedure; the elimination of abdominal colostomy in rectal and sigmoid growths with establishment of a perineal anus, with or without preservation of the sphincters.

Early Diagnosis of Carcinoma of the Fundus, J. P. Pratt, M.D., Detroit, Mich.: Any vaginal bleeding after the menopause arouses suspicion of malignancy. Microscopic bleeding is important for early diagnosis. This is especially true when the cervix appears normal. Before the menopause, carcinoma occasionally originates in hyperplasia of the endometrium. All curettings must be examined carefully for evidence of malignancy. Dr. Pratt recommended that the patient be instructed to keep a graphic record of menstruation for three years. This sometimes leads to determination of early carcinoma. He also emphasized the necessity of careful education of patients as essential to secure earlier diagnosis.

Three-Year End-Results of Carcinoma of the Female Genital Tract Treated with 800 K.V. Roentgen Rays, Henry Schmitz, M.D., Chicago, Ill.: The effect of the Roentgen ray deep therapy is determined by histologic changes in the carcinoma cells. Sections were removed before treatment was begun and thereafter every eight days until the treatment was finished. These sections were studied every two weeks until local healing ensued. The radiation doses were 1,000, 2,000, 3,000, and 4,000 after one, two, three, and four weeks. The histologic changes due to the Roentgen rays of 800 K.V. were compared with those obtained with gamma rays. They were found to be essentially the same.

This treatment, from May 1, 1933, to December 1, 1934, showed a healing of 50 per cent in 34 patients.

Results after similar periods obtained with radium and 140 K.V. Roentgen rays were 20.8 per cent in 24 cases and with radium and 200 K.V. Roentgen rays were

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29.2 per cent in 48 cases. It is therefore probable that the use of ultrahigh voltage Roentgen rays will give superior percentages of good end-results or cures after a period of five years.

Pelvic Tuberculosis, James E. King, M.D., Buffalo, N. Y.: Dr. King reviewed 26 cases of pelvic tuberculosis, laying particular stress upon the postoperative sanatorium treatment.

The Surgical Treatment of Ovarian Dysfunctions, J. L. Reycraft, M.D., Cleveland, Ohio: Different types of surgical treatment were reviewed and a series of cases presented, showing the functional effect of excision of the major portion of the ovarian cortex.

The Problem of Endometriosis, Dr. Daniel Dougal, Manchester 3, England: Dr. Dougal was the guest speaker at the meeting and delivered the Joseph Price Oration.

Caesarean Section in Infected Cases, Willard R. Cooke, M.D., Galveston, Tex.: Dr. Cook called attention to the unsatisfactory results of the Kroenig, Latzko, Hirst, Porro, Portes operations and proposed a modification of the Hirst principle, namely the isolation of the pelvic cavity by uniting the peritoneum of the uterus with the parietal peritoneum.

Frank-Geist Operation for Congenital Absence of the Vagina, Walter T. Dannreuther, M.D., New York, N. Y.: Dr. Dannreuther reviewed the various methods of constructing the vaginal canal, stressing the unsatisfactory results in most of them. The Frank-Geist operation has been popularized as the "satchel handle" operation, which is characterized by the construction of a canal of the skin and integument of the thigh and the dissection of a space anterior to the rectum into which the "satchel handle" is introduced.

The Treatment of Vesicovaginal Fistula, Cameron Duncan, M.D., Brooklyn, N. Y.: Dr. Duncan emphasized the necessity of cystoscopic examination, the determination of the function of the kidneys, the exact relation of the ureters to the fistula as necessary preliminaries to the operation.

Gynoplastic Repair, Following Delivery, Raymond C. King, M.D., Toledo, Ohio: Dr. King advocated routine examination of the cervix and vagina immediately following delivery. He stated that the immediate repair of recent injuries was superior to the intermediate repair (five to ten days after delivery). He called attention to the fact that intermediate or secondary repairs can be done immediately after delivery, but that it is wiser to postpone such operations to a later date.

Presidential Address (Our Association, Its Privileges, Accomplishments and Its Future), James W. Kennedy, M.D., Philadelphia, Pa.: This was a most inspiring review of the past history and future of the specialty of obstetrics and gynecology, paying high tribute to Dr. Kennedy's former chief, Dr. Joseph Price.

The Preliminary Stage of Labor, Buford G. Hamilton, M.D., Kansas City, Mo.: By the preliminary period of labor is designated all the presumptive signs of labor that may be present before there is evidence of the progressive softening, effacement, and dilatation of the cervix. Dr. Hamilton classified labor under three headings: true labor, false labor, or preliminary labor. In the latter there may be pains for days, with no progress, but the delivery is normal with proper handling. He stressed that during this period of prolonged ineffective pains interference is contraindicated.

Respiration and Pulmonary Ventilation in Nonpregnant, Pregnant and Puerperal Women with an Interpretation of the Acid Base Balance During Normal Pregnancy, E. D. Plass, M.D., Iowa City, Ia.: The respiratory rate, the volume of tidal air, and the minute volume of respired air increase during pregnancy. Associated with these changes there is an increase in the minute volumes of expired CO_2 and of absorbed O_2 and a rise in the ratio of the minute volume of respired air to the minute volume of expired carbon dioxide. The acid-base balance in the blood of pregnant women represents a compensated CO_2 deficit based upon a physiologic hyperventilation, the gradual development of which prevents any consistent rise in the blood pH by permitting a reduction of the plasma bicarbonate proportional to the lowering of the CO_2 content.

What Is the Correct Interpretation of the Term Test of Labor? E. L. King, M.D., New Orleans, La.: There is a lack of uniformity in the definitions of the "test of labor" which is found in the various textbooks on obstetrics. This term, of course, is applied to the conduct of labor in a case of borderline contracted pelvis. The question of the performance of Caesarean section is based upon the findings after the "test of labor."

The Relationship of Fetal Birth Injuries to Obstetrical Difficulties, W. A. Scott, M.D., Toronto, Canada: There is a tendency to ascribe fetal birth injuries to poor obstetrics. The practice of good obstetrics implies a certain fetal mortality and if attempts are made to eliminate this mortality, poor obstetrics will be done with an increasing maternal death rate.

This paper is a consideration of the factors in fetal birth injuries as encountered by conscientious obstetricians.

Nutritional Diseases Associated with Late Toxemia, R. A. Ross, M.D., Durham, N. C.: The apparent paradoxes in the incidence, causation, classification, treatment, and prognosis of patients with late toxemia of pregnancy have been repeatedly emphasized. Dr. Ross has been impressed with certain variances occurring in patients of North Carolina. His report comprises a five-year review of the problem of late toxemia of pregnancy in a state which is essentially rural, its incidence in a general hospital, and its development in an institution that has adequate professional supervision. The results are at variance with the findings of studies in other localities. He emphasized that the difference was probably due to the peculiarities in the diet of the poorer patients with which they have to deal.

The speaker of the evening at the banquet was **Francis P. Gaines,** President, Washington and Lee University, Lexington, Va. Dr. Gaines, a great orator and scholar, gave a scholarly and inspiring address on the **Overtones of Education.**

Book Reviews

A Brief Outline of Modern Treatment of Fractures. Ed. 2. By H. Waldo Spiers. Pp. 133, with 109 illustrations and 5 plates. Baltimore, 1937, William Wood & Company. $2.

In this small book the author has attempted the extremely difficult feat of compressing the subject matter of fracture treatment within the limits of the students' time and needs. The plan and general arrangement of the book are excellent and good use has been made of line drawings to illustrate the text. All padding in the form of reviews of the literature and extended discussion and debate has been rigorously excluded.

As a supplement to the teaching of students, however, the book is open to some few criticisms. The author has compressed his subject matter into the smallest possible compass, but he has not well adapted his style to the limits of his space. By careful editing and repeating polishing much space which is sorely needed for expansion and elaboration of certain parts could be gained.

The chapters on the treatment of individual fractures are, on the whole, good. Fractures of the clavicle are discussed in the traditional manner but without mention of Boehler's ideas on the subject. Dislocation of the shoulder joint is briefly and not too well considered, and unfortunately the original method of reduction as presented by Kocher is not accurately described. Fractures of the humerus are well treated, as are the fractures of the elbow joint. Colles fracture is considered in the orthodox manner, but no mention is made of Boehler's treatment. Fractures of the hand and carpal bone receive adequate mention for a book of this type. Fractures of the vertebrae and ribs are well described and discussed. The chapters on fractures of the hip and femoral shaft are remarkably good and compare favorably with those in any of the large texts.

Traitement Chirurgical du Cancer du Colon Pelvien. By Pierre Bertrand and E. Corajod. Paper. Pp. 207, with 35 illustrations. Paris, 1936, Masson and Cie. 30 fr.

This book is one of the monographs on sharply delimited subjects so popular with the French and so well done by them. The authors are the former and the present Chef de Clinique Chirurgical à la Faculté de Médecine de Lyon, also assistants to Professor Tixier of that clinic. The work is a critical analysis of 155 patients with cancer of the sigmoid colon treated in the surgical clinics of Professor Tixier and Doctor Paul Santy. The book is divided into two parts, the first dealing with the anatomy, pathology and clinical manifestations and the diagnosis of the part and the disease. These subjects are covered systematically but with brevity and without evidence of originality or personal authority. The second and larger part of the book is devoted to a consideration of treatment.

The historical development of the operative procedures is well done and most interesting, showing that American surgical literature has not given credit to the French for originating many commonly used technical procedures. All operations with their many minor modifications that have been used in treating cancer of the sigmoid are described briefly and illustrated with rather schematic line drawings

that illustrate principles but not details. The literature of the subject has not been fully covered but perhaps that is not necessary in a work of this limited scope. The analysis of the 155 cases is of great interest in showing conditions faced by our French colleagues and especially in showing how they meet these problems. The operability for cure is 50 per cent, about that in many clinics in this country. The operative mortality and end-results in the various types of surgical attack are carefully analyzed and will be read with profit by anyone doing this type of surgery.

The first part of the monograph could be read with profit by the medical student; the second part, studied with interest by the surgeon as a comparison between his work and that of French surgery. It is worthy of note that at the present rate of exchange this book costs just over $1.00. This low price is accounted for in part by the simplicity of the cuts and the paper binding, but we may well inquire whether there might not be a place in our literature for inexpensive books of this type in which subjects are covered comprehensively enough for the medical student, interne, and young surgeon. Surgery advances with such rapidity that the most expensive book soon becomes obsolete.

Tumors of the Nervous System (Volume XVI of a series of research publications, The Proceedings of the Association for Research in Nervous and Mental Diseases, New York, Dec. 27 and 28, 1935). Pp. 493, with 213 illustrations, Baltimore, 1937, The Williams & Wilkins Co. $7.50.

This book is a most excellent compilation of some of the recent advances in the investigation of tumors of the nervous system. It is composed of a series of individual articles written by investigators well versed in their particular fields. The subject matter comprising this book was presented at the annual meeting of the Association for Research of Nervous and Mental Diseases. Discussions of the papers are included after each chapter. These discussions help to elucidate the differences of opinion upon various subjects and are a valuable adjunct to the book.

As a whole, the articles are well written and concise. Certain chapters merit special comment. The chapter on "The Effect of Irradiation on Gliomas" is the result of a survey of material obtained by the pooling of cases from numerous clinics. This cooperative study has resulted in information which probably would be very difficult to duplicate. The study on "The Gliomas of the Central Nervous System" is an exceptionally well-written comprehensive review of the histologic structure of these various tumors and of the preoperative duration of symptoms as well as the average survival time in the various types of gliomas. The study of meningiomas has been approached from a new angle, and an attempt has been made to trace the origin of these tumors in order to account for the extreme variation in their structure. In this work the author very logically classifies the meningiomas according to their origin, thus emulating a procedure that already has been carried out for the gliomas. The final chapters are devoted to a study of "Tumors of the Peripheral Nerves." The authors here have succeeded in condensing and clarifying a most diversified and complicated field into a few well-organized chapters.

This publication, however, has certain definite weaknesses. The space allotted for the discussion of some of the subjects is certainly not in the proper proportion to their relative importance, thus producing an improper balance of the subject matter of the text. For example, an entire chapter is devoted to the study of "Ependymomas"—incidentally, an excellent chapter that warrants reading—while

such tumors as pinealomas, oligodendrogliomas, and spongioblastoma polare are dismissed with only a very short discussion. Also, some forty-eight pages are devoted to a discussion of tumors and cysts of the cerebellopontine angle and their relation to the lateral recesses of the fourth ventricle. Such a lengthy discourse is somewhat out of keeping with the importance of this material to the rest of the book. The text is likewise lacking in completeness as a study of tumors of the central nervous system. The entire group of vascular tumors is omitted. Also numerous other less common lesions, such as teratomas, lipomas, and granulomatous lesions as tuberculomas and syphilomas, are not mentioned.

For the material covered, the book certainly can be recommended as an authoritative and well-written statement, but it cannot be used as a reference book for all tumors of the nervous system.

A Synopsis of Genito-Urinary Diseases. By Austin I. Dodson. Pp. 272, with 111 illustrations, St. Louis, 1937, The C. V. Mosby Company. $3.

This little book is designed to furnish the medical student and general practitioner with a convenient hand book of urologic information. This is the second edition, the first having appeared in 1934. The newer work is considerably improved over the original, both in the arrangement and treatment of subject matter and in the number of illustrations.

The outstanding feature of the book is its compactness and adherence to fundamentals. The author apparently realized the importance of describing in detail the points of technique in the performance of the simplest urologic procedures, since the book will be used for the most part by men entirely unfamiliar with urology. This alone makes it a valuable reference work, as these points are commonly slurred over or omitted in the larger, standard texts. The more advanced aspects of treatment, notably major urologic surgery, are passed over with the barest mention, as these are admittedly not within the scope of such a synopsis. Attention is paid throughout to the more common urologic conditions, the rarer diseases being mentioned but not emphasized.

The author has brought his book up to date and has included all of the newer urinary antiseptics in his discussion of upper tract infections. In addition to this, complete diet lists are furnished, which can easily be referred to in prescribing for patients. However, no misleading claims or inferences are made wherever new methods of treatment are discussed, and it is clearly stated in each instance that their efficacy and safety have yet to be tested by sufficient time and experience.

It may be seen from the above that this little book fulfills its purpose admirably and can unhesitatingly be recommended as a ready source of urologic information to any one desiring it.